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Canadian Atlantic Fisheries
Scientific Advisory Committee

CAFSAC Research Document 87/94

Comité scientifique consultatif des
pêches canadiennes dans d'Atlantique

CSCPCA Document de recherche 87/94

Status of the Atlantic Cod Stock on Georges Bank, NAFO Division 5Z and Subarea 6, in 1986

by

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Abstract

Status of the Atlantic cod stock in NAFO Division 5Z and Subarea 6 is reviewed incorporating 1986 data. Total catch (USA and Canada) in 1986 was 26083 t, of which Canada landed 8508 t. Canadian standardized otter trawl catch rates have declined since 1977 but showed some improvement in 1982 and 1985, when strong year-classes were recruiting to the fishery. The 1986 (0.6 t/hr) level was slightly less than that in 1985. USA catch rates for both directed and total effort were at their lowest since 1978. A contrast in Canadian and USA CPUE may be the result of a change in exploitation pattern imposed by recognition of the International boundary. USA research survey indices are at relatively low levels but show a slight increase in 1986. The autumn USA surveys have caught above average numbers of the 1980 and 1985 year-classes while the 1981, 82 and 84 year-classes appear to be well below average. Results of SPA, calibrated with autumn survey indices, indicate a fishing mortality of 0.7 in 1986 with a 1982-86 mean fully recruited F of 0.68. The present analysis indicates levels of fishing mortality higher than those estimated in previous reports. Biomass has shown a steady declined from 95000 t in 1978 to 34000 t in 1986. The current F0.1 yield for this stock is less than 15000 t and limitation of catches to this level will require bilateral management with the USA.

Résumé

On examine l'état des stocks de morue de l'Atlantique dans la division 5Z et la sous-zone 6 de l'OPANO en y incluant les données de 1986. La prise totale en 1986, pour le Canada et les Etats-Unis était de 26 083 t, dont 8508 t pour le Canada. Les taux de prise normalisés pour les chalutiers canadiens, en déclin depuis 1977, ont augmenté en 1982 et en 1985, à cause du recrutement d'importantes classes d'âge. En 1986, le taux de prise (0,6 t par heure) était légèrement inférieur à celui de 1985. Cependant, les taux de prise américains (pêche dirigée et pêche totale) étaient les plus bas depuis 1978. La différence entre les PUE des Etats-Unis et du Canada peut provenir d'une modification du mode d'exploitation imposé par la reconnaissance de la frontière internationale. Les indices obtenus par les relevés de recherche américains sont relativement bas, mais ont augmenté légèrement en 1986. Les relevés d'automne américains montrent des prises supérieures à la moyenne pour les classes d'âge 1980 et 1985; par contre, les prises dans les classes d'âge 1981, 1982 et 1984 semblent nettement inférieures à la moyenne. Les résultats de l'ASP, étalonnée à l'aide des indices obtenus par les relevés d'automne, indiquent une mortalité par pêche de 0,7 en 1986 pour un F moyen de 0,68 entre 1982 et 1986 (stock pleinement recruté). L'analyse indique des niveaux de mortalité par pêche plus élevés que ceux prévus par les études antérieures. La biomasse a diminué de façon constante, passant de 95 000 t en 1978 à 34 000 t en 1986. Le rendement actuel de ce stock à $F_{0,1}$ est inférieur à 15 000 t et la limitation des prises devra se faire par entente bilatérale avec les Etats-Unis.

Introduction

The size of the Atlantic cod population in NAFO Division 5Z (Figure 1) and Subarea 6 was evaluated by Brown and Heyerdahl in 1972 through the examination of research survey data and commercial catch rates. Serchuk et al (1977, 1978) conducted virtual population analysis of the catch data but considered results to be suspect because of uncertainties in the reliability of reported catch statistics.

Catch statistics since 1977, when foreign fleets were excluded from the 200 mile economic zones of Canada and the USA, are thought to be more reliable. There have been no reported landings by foreign fleets since 1978.

The fishery has been managed independently by Canada and the USA since 1978. Canada recommended TAC's for 1978-84, while the USA has followed their Groundfish Management Plan since 1981. Canada has set Canadian TAC's for 1985-87.

Hunt and Waiwood (1984), in a review of stock status, suggested a fully recruited fishing mortality of 0.4 in 1983. However, their report was not based on SPA due to an inadequate time series for catch at age in the fishery.

Hunt and Waiwood (1985) used the 1978-84 catch at age to estimate population status and their results indicated a fully recruited fishing mortality of about 0.6 in 1984, an F of 0.65 to take 40000 t in 1985 and an F0.1 catch in 1986 of about 11000 t.

Hunt and Gavaris (1986) examined catch data from 1978-85 and subjected these data to sequential population analysis (SPA). Research survey data were also used to examine stock structure. Their results indicated a fully recruited fishing mortality in 1985 of 0.45, based primarily on relationships between VPA numbers at age and research survey indices.

The present report incorporates 1986 commercial catch data and research survey results to estimate stock status in 1986.

Cod in Division 5Z are taken by both Canada and the USA and all data relating to USA catches, CPUE and research vessel surveys were provided by the National Marine Fisheries Service (NMFS) through Dr. Fred Serchuk at the Woods Hole, Mass., Laboratory.

Trends in Reported Landings

Annual Landings

The USA has been the main harvester of cod in Division 5Z and Subarea 6, although landings by other countries were high in the mid-1960 time period

(Table 1, Fig. 2). The Canadian catch was also high in this period, peaking at 15601 t in 1966. Total landings declined to about 20000 t in 1976 but then increased to a maximum recorded value of 57195 t in 1982.

Total landings in 1983 were 48928 t, a decline of over 8000 t from 1982, and fell by an additional 10000 t to 38676 t in 1984. This is about 68% of the 1982 level and reflects a sharp reduction in landings by Canada in both 1983 and 1984. Reported landings remained constant between 1984 and 1985 (37269 t) with a decline of 6000 t in USA landings being offset by an increase of 5000 t by Canada. In 1986, landings by both USA (17575 t) and Canada (8508 t) declined from 1985 levels and the total catch decreased by 30% to 26083 t, the lowest since 1976.

Fishery by Country and Gear

The USA cod fishery is dominated by otter trawlers (Table 2) that operate throughout Division 5Z. Catches by other gears such as gill nets, Danish seines and longlines have accounted for 10-15% of the total USA catch. A substantial "recreational" fishery also exists (Serchuk and Wigley,1986). Catches from the sport fishery have been stable between 8000-9000 t and the estimated 1985 catch was 8982 t. Most of this catch is taken inshore in in Subarea 6.

Canadian catches of cod, since 1978, were taken on the "northeast peak" of Georges Bank (unit areas 5ZEj and 5ZEm) primarily between April and November. Landings have been dominated by otter trawlers, except for 1984 (Table 3, Fig. 3). This gear took 70% of the total catch in 1982, was 57% in 1983 and only 13% (745 t) in 1984. Catches by longliners were about 5000 t between 1981 and 1984. Catches in 1985 increased to 7600 t by otter trawlers and decreased to 2800 t by longliners. In 1986, both otter trawl and longline catches decreased (19% and 29%, respectively) while the catch by other gears (primarily gillnet) increased from 88 to 292 t.

The Fishery in 1987

Preliminary 1987 Canadian quota reports indicate a catch of 7342 t by otter trawl and 2254 t by longline by late-August for a total of 9596 t. Catches by small TC 2 and 3 otter trawlers account for 6589 t or about 69% of the total. No estimates of the 1987 USA catch are available at the present time.

A total of 20 samples were collected by port technicians, 17 from otter trawl catches, 2 from longliners and 1 from gillnet. Ageing of these samples has not been completed but examination of the length frequency data indicates that fish between 43 and 61 cm accounted for over 70% of the total catch. Length at age data suggest this group of fish is composed primarily of two and three year olds or the 1985 and 1984 year-class.

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Age Composition of the Commercial Catch

Sampling Intensity

Sampling coverage of the Canadian fishery averaged about one sample per 1000 t landed, since 1980, and is biased towards otter trawl catches with fair coverage in 1978, 1984 and 1985 but poor coverage in 1979, 80 and 83. Only 7 samples, all from longline gear, were taken in 1984 from a total catch of less than 6000 t. In 1985, 18 samples were collected and 19 in 1986.

USA sampling has increased substantially since 1980, when 70 samples were collected, and is now at a level of over 150 samples per year. Sufficient samples are collected to estimate catch at age by gear, quarter and market category for USA landings.

Age Composition

Estimated removals at age prior to 1978 given by Serchuk et al(1977) are probably under-estimated and are not considered reliable because of suspected under-reporting of foreign fleet catches (Serchuk & Wigley, 1986). Catch composition of USA landings in 1978-85 (Serchuk & Wigley, 1986) and for 1986 were provided by Dr. F. Serchuk, NMFS, Woods Hole, Mass.

Canadian samples were used to obtain statistics by age according to the method described by Gavaris and Gavaris (1983). The bias introduced by applying otter trawl length frequencies to partition longline catches may be significant in years lacking samples for this gear. A summary of catches and samples used to estimate removals at age for 1978-85 is given in Hunt and Gavaris (1986) and a similar summary for 1986 is given in Table 4. Percent age composition of Canadian catches are shown in Table 5.

Values for a and b, in the length weight relationship, derived from Canadian commercial sampling data, were a=0.0000163 and b=2.9048 for round weight in kilograms and length in centimeters. These compare to values of a=0.000008104 and b=3.0521 for USA survey data (Serchuk et al, 1982). Canadian estimates were considered to be more representative of the fishery since the USA values are derived from October samples when weight of fish is more influenced by maturity stage.

Age groups 2-5 account for most of the yield but a difference in the age composition between Canada and USA has been noted (Hunt and Gavaris, 1986). USA catches show a higher proportion at age 2 in some years and in 1982-84 this age group accounted for more than twice the percentage taken by Canada at age two. The 1984 Canadian catch at age is influenced by the small otter trawl catch.

An exchange of 140 otoliths between USA and Canadian readers resulted in 74% inter-reader agreement. The same sample was examined during a workshop and through discussion a total of 18 ages were changed (seven US ages increased by one to agree with Canadian and 11 Canadian ages decreased

by one to agree with USA). Final level of agreement was 87.9% and most of the disagreements occurred at age 4+, although relatively small numbers of age 1 and 2 fish were included in the sample. This level of agreement suggested that the best estimate of total catch at age would be based on the sum of catch at age by Canada and USA. Results are given in Table 6.

Mean weight and length at age for Canadian and USA catches are given in Tables 7 and 8, with the "+" group set to 115 cm and 15.0 kg. Means for the total catch were derived by weighting with the catch in numbers for each country. An error in the 1980 values calculated by Hunt and Gavaris (1986) was noted and the corrected means are given in Tables 7 and 8.

Stock Abundance Trends

Research Surveys

Random, depth-stratified bottom trawl surveys have been conducted by the USA in the autumn since 1963 and a spring survey was added in 1968. A summer survey was conducted from 1977 to 1981. Surveys in Subdivision 5Ze were completed by Canada in March, 1984,86-87. Mean catch per tow in numbers by age group for each of the USA surveys is given in Table 9a and the mean catch per tow in numbers and weight in Table 10, Fig. 4,5. No adjustment for different gears or vessels used during the time series has been made. The spring survey used the larger "Yankee 41" trawl from 1973-81 and considerable differences in catch per tow could be anticipated. Total net opening of the "41" trawl is about 1.7 times the opening of the "Yankee 36".

New trawl doors have been used for both spring and autumn surveys since 1985. Preliminary analysis of a study to develop conversion factors indicates the new trawl doors are more effective and would increase the catches of cod and haddock (pers. comm., Dr. F. Serchuk, NMFS). The value of the conversion factor has not been resolved and catches since 1985 should be considered an over-estimate relative to pre-1985 levels.

The spring survey has shown a decline in 0+ numbers between 1981-84, when the same sampling gear was used, and was at the lowest observed level in 1984 but increased in both 1985 and 1986. The 1987 survey declined to the second lowest level since 1971. The autumn survey has been relatively stable since 1982 with below average catches and shows a slight increase in the 1986 survey.

Canada has conducted a stratified random bottom trawl survey using a Western IIa trawl in Subdivision 5Ze during March 1986 and 1987. Results of this survey are given in Table 9b but catch levels are not directly comparable with USA catches due to the difference in vessel and gear type.

Canada also completed a fixed station survey of the Northeast peak of Georges Bank during July of 1987. This survey was designed to estimate the abundance and distribution of cod and haddock relative to commercial fishing operations. A total of 61 stations were completed and preliminary analysis of the data indicates a mean catch per tow of 19.1 in numbers and 37.2 in

kg for cod. Catch per tow is summarized in Figure 6 and indicates highest abundance on the Canadian side of the International boundary. A comparison of the length distribution from the survey with commercial catch is given in Figure 7. Results indicate a similar length distribution for survey and commercial catches at lengths of over 40 cm, but the survey caught more fish at lengths less than 40 cm. The 1987 year-class at age 0 was evident at lengths of 4-7 cm and the 1986 year-class accounted for the difference at lengths of 22-37 cm. Both distributions are dominated by a mode at 49-52 cm which would be comprised primarily of the 1985 year-class at age two.

Commercial Catch Rates

Catch and effort statistics by month, for the Canadian fishery, were derived from Table 5 of the NAFO/ICNAF Statistical Bulletins for 1967-83. Data for 1984-86 were obtained from the Canadian Department of Fisheries and Oceans. A multiplicative model (Gavaris, 1980) was used. Due to previous observations regarding systematic bias caused by truncation of this type of data (Gavaris and Sinclair, 1985), all observations where either the catch was less than 10 t or the effort was less than 10 hours were excluded from the analysis.

Examination of the residuals from the preliminary unweighted analysis resulted in the exclusion of three observations: OTB2-4, April 1967; OTB2-2 December 1968; OTB2-2, October 1982. There did not appear to be any annual trends in either month or gear residuals but these residuals showed that observations with lower catch and effort were more variable. Therefore a weighted analysis was applied. An iterative procedure described by Judge et al (1980) was used to estimate the weights based on the partitioning of residuals along a logarithmic (catch x effort) scale. The analysis of variance from the weighted regression (Table 11) indicates that months do not account for much of the systematic variation. The coefficients for gears follow an intuitive pattern with larger vessels associated with greater fishing power.

The results of the analysis are shown in Table 11 in both the ln and re-transformed linear scale. Trends in the linear scale (Figures 8 and 9) indicate fairly low CPUE in the mid-1970's with an abrupt increase in 1977 probably due to the recruitment of the 1975 year-class. This is followed by a general decline, although catch rates increased somewhat in 1981-82 and 1985, probably due to recruitment of the 1980 and 1983 year-classes, respectively. The 1986 CPUE declined slightly from the 1985 level.

USA catch rates (Serchuk & Wigley, 1986) are reproduced in Table 12 and Fig. 10. Landings by TC 2, 3 and 4 otter trawlers for all trips and >50% cod trips are given. Catch rates in all categories show a general decline between 1978 and 1986 and, without exception, the catch rates in 1986 were the lowest since 1978. The value of 2.15 in 1985 for all trips reported by Hunt and Gavaris (1986) was found to be an error and the correct value of 1.15 confirms the 1978-86 trend. Serchuk & Wigley (1986) also give

catch rates for USA otter trawlers operating in Subdivision 5Ze (Northeast peak and edge area of Georges Bank) during July-September, the same area and time as the main Canadian fishery. He concludes that the trends shown in this subset and in the total CPUE are similar. A comparison of USA and Canadian CPUE for different times and areas are given in Table 13 and summarized in Figure 11. Values were standardized to the mean for the 1978-86 time period to allow comparison of relative CPUE.

The apparent contrast between USA and Canadian CPUE trends, the increasing proportion of the total catch taken by Canada and the change in spatial distribution of fleets since 1985, due to the International boundary indicates a requirement to develop a weighted, by country, index of CPUE. USA CPUE (t/day) and Canadian CPUE (t/hr) are not directly comparable and it was necessary to use a relative index. This was estimated by calculating directed effort (total catch/CPUE) independently for each country's catch and CPUE for 1978-86 and standardizing these values to the mean. The resultant relative index for each country was weighted by catch, the two values summed and divided by total catch to derive a total relative index for the fishery. Values used in the calculation are shown in Table 14 and Figure 12.

Commercial catch rates and resultant effort are strongly influenced by the strength of recruiting year-classes at age two and three and these age groups have accounted for 50-70% of the catch in numbers. Estimates of partial recruitment at age two range from 30-80% (see page 11) and the potential for discards of under-size fish (<40 cm) may be high. Examination of length frequency data for commercial landings (see Hunt and Gavaris, 1986 and Figure 7) indicates that less than 5% of landings are composed of cod under 40 cm. Sampling of catches at sea by the International Observer Program (IOP) was completed in 1982-83 and 1985-87 and analysis of these length frequency data indicate a length distribution similar to on-shore (landings) samples. Anecdotal information from interviews with fishermen in 1986, when the 1985 year-class would have been liable to discarding, also indicates a low level of culling. These results suggest that discarding of cod is not a major concern in the Canadian commercial fishery.

Survey Index of Recruitment

Indices of recruitment were obtained from the autumn survey catch per tow at ages 0, 1 and 2 for the 1962-85 year-classes. The catch per tow at age was normalized to the mean of the 1962-86 catch per tow and the average at ages 0+1 and 1+2 selected as an survey index of relative abundance. The calculated indices are given in Table 15 and Fig. 13. The 1+2 index is influenced by the effect of fishing mortality on age two fish. The 1966, 1971 and 1975 are dominant, with the 1980 year-class above average, 1981 and 1982 below average, and the 1983 year-class also above average. The 1984 year-class is well below average while the 1985 year-class catch at age 0+1 is the highest since the 1975 year-class. The 1986 year-class at age 0 in the autumn survey appears to be one of the smallest in the time series, but is the largest at age 1 in the 1987 spring survey over the 1982-87

time period, when the same survey gear was used.

Hunt and Gavaris (1986), in a comparison of catch per tow in successive years for the same year-class, note poor correlation for the spring surveys but a higher level for the autumn surveys. It also appears that the 0-group catch in the autumn survey is indicative of year-class size. Catch of 0-group fish in the spring survey appears to be inconsistent with the size of a year-class at ages 1+. That survey may sample the results of occasional early spawning (December) rather than the main spawning later in the winter.

Total Mortality Estimates

Calculated values of total mortality (Z) and derived estimates of F based on USA spring and autumn survey catch per tow are given in Table 16. The ratio of numbers at 4+ to numbers at 5+ from spring surveys and the ratio of numbers at 3+ to numbers at 4+ from the autumn survey in several time intervals were used to estimate mortality. Using the time series for 1982-86 in spring surveys avoids the change in gear used and estimates a Z of 0.45 and an F of 0.25. The 1982-86 autumn surveys indicate a Z of 1.29 and 1.09 fishing mortality over the last five years of the fishery. For the last three years (1984-86), the spring survey indicates a Z of 0.27 and the autumn survey a Z of 0.66 with fishing mortalities of 0.07 and 0.46. However, negative Z values between 1984 and 1985 in the spring survey and between 1983 and 1984 in the autumn survey place some doubt on the validity of these estimates.

Estimates derived from the Canadian March survey for ages 3+, 4+ and 5+ between 1986 and 1987 indicate a Z of 0.7 to 0.8 with a resultant fishing mortality of 0.5 to 0.6 for 1986.

Sequential Population Analysis (SPA)

Estimates of total mortality (Z) derived from survey results indicate a fishing mortality of above 0.5 for recent years. Full recruitment at age three was assumed based on the historical pattern in the F matrix and the relationship between SPA and survey numbers. Trial runs of SPA with the 1978-86 catch at age and terminal fishing mortality (Ft) between 0.4 and 0.8 were made to estimate population numbers and fishing mortality. Results of SPA were regressed on the corresponding index from the autumn research survey and the weighted (by population) 3+ F on directed effort derived from Canadian, USA and combined CPUE.

Mean 3+ fishing mortalities, weighted by population numbers, were regressed on standardized effort derived from the Canadian OTB CPUE. Best correlation and minimization of residuals occurred with an Ft of 0.30 or less, although the 1986 F appeared to be under-estimated and minimization of the 1986 residual occurred with higher values of Ft. Regression of mean 3+ F on directed effort derived from USA CPUE was optimized at an Ft of 0.60, based on R-squared and residual values.

Regression of mean 3+ F on the index of relative effort derived from

USA and Canadian CPUE indicated an Ft of 0.45 based on R-squared and minimization of residuals. Residuals for 1984-86, the sum of residuals and sum of squares of residuals for the last three years were consistent in indicating an Ft above 0.40 and less than 0.50. Results are given in Table 17 and summarized in Figure 14.

A model, developed by Gavaris and Waiwood (1986) and modified by Gavaris (1987), was also used to estimate fishing mortality in 1986. The relationship between the USA autumn research survey and estimated population numbers derived from SPA with different input levels if Ft is described by the following equation:

$$\ln Yij = \ln[\alpha Xi + \beta Xi \gamma_0 \prod_j \gamma_j Xj] + \epsilon ij$$

where

- Y - observed index value or SPA value
- i - index for source ie. survey year or SPA
- j - index for year
- α - scaling factor (additive constant)
- β - relative source effect (proportionality constant)
- X - indicator variables with value of 0 or 1
- γ_0 - reference mean
- γ - relative year effect
- ϵ - error

This model allows for error in both the survey index and the estimated SPA population. A logarithmic transformation was used to stabilize variances in both the survey index and catch at age.

To estimate fully recruited fishing mortality, SPA 4+ numbers and autumn survey 3+ numbers, lagged by one year, were examined. Observations were closely clustered and the intercept term was not included. Based on minimization of mean squared residuals for the regression, with all observations included, a fully recruited fishing mortality in 1986 was estimated to be 0.7. Results are shown below:

RV 3+ numbers and SPA 4+ numbers

Fully recruited Ft	0.5	0.6	0.7	0.8
Mean squared residuals	0.2407	0.2302	0.2266	0.2278

and the relationship for Ft=0.7 is shown in Figures 15 and 16.

With Ft set to 0.7, trial values of fishing mortality at age two in 1986 were input to estimate population number at age two. The relationship between SPA age 2 and survey age one indicated a fishing mortality of 0.25, based on minimization of mean square residuals, corresponding to a partial recruitment of 35.7% in 1986. Results are shown in Figure 17.

The relationship between SPA number at age 1 and survey number at age

one indicated a fishing mortality on age 1 in 1986 of 0.0045, based on minimization of mean square residuals, corresponding to a partial recruitment of 0.64% in 1986. Use of the autumn age one index without lag and the SPA age one number was justified on the basis of expected low fishing mortality at age one and the minimal effect of catches by the commercial fishery prior to the autumn survey in the same year. Results are shown in Figure 18.

Residuals (ln) for recent year-classes using 0.7 for fully recruited fishing mortality and 0.25 and 0.0045 for ages two and one, respectively, in 1986 are shown below:

	Year			
Age	1984	1985	1986	1987
1	-.0914	-.1139	+.0988	-.0113
2	-.1303	+.2175	+.0129	-.0756
3+	+.3316	-.2564	+.1416	-.0465

Residuals appear to be "balanced" along cohorts with both positive and negative values and no apparent bias or trend.

Results of regression analysis suggest that the fully recruited fishing mortality in 1986 may exceed 0.5, although the relationships between mean 3+ F and effort were inconsistent with those derived from population numbers. Catch rates for the USA are probably influenced by exclusion from the Northeast peak area of the Bank since 1985 and it is unlikely that the Canadian, USA or combined CPUE would provide a index of abundance which is consistent over time. Further research will be required to establish a suitable index of CPUE and derived effort. For the interim, the relationship between SPA number at age and the USA autumn survey was considered to provide the least biased estimate of Ft and the derived value of 0.7 was accepted as the best approximation for 1986.

Final SPA Run

Population number, biomass and fishing mortality were calculated from SPA using a fully recruited F in 1986 of 0.70 and a partial recruitment vector of 0.006, 0.357, and 1 for ages 1, 2 and 3+ in 1986. Results are given in Table 18.

Fishing mortality (3+) increased from a mean of 0.393 in 1978 to a high of 0.824 in 1985 and averaged to 0.680 for 1982-86.

Estimated 1+ population numbers ranged from 69-84 million for 1978-82 but were about 50 million in 1983 and 1984, reflecting the small size of of the 1982 year-class at age 1 and 2. Numbers at age 3+ were 13 million in 1985, the lowest in the series, but the size of the 1982 year-class is a

dominant factor. Similar results are apparent in the estimate of population biomass and the 3+ biomass was below 34000 t in 1985. This is primarily the effect of high catches of the 1980 year-class at ages 2, 3 and 4 as well as low recruitment of the 1982 year-class. The increase in both numbers and biomass in 1986 is primarily the effect of the 1983 and 1985 year-classes. Estimated recruitment at age 1 and estimated 3+ biomass are given in Figures 19 and 20.

Yield Per Recruit Analysis

Estimates of mean weight at age for ages 1-15 and partial recruitment at ages 1-15 were used in the Thompson and Bell model to determine F0.1, Fmax and equilibrium yield for the Georges Bank cod stock. Mean weight for ages 1-9 were estimated from the observed weight at age in the commercial fishery for 1978-86. Mean weights at age for ages 10-15 were estimated using growth parameters derived from the average length at age for 1978-86. Parameters of the von Bertalanffy curve were

Asymtotic length	138.03 cm
Brody co-efficient	0.1395
T-zero	-0.5415

Partial recruitment at ages 1 and 2 were estimated from the converged part of the F matrix with the following results:

Year	PR1	PR2
83	-	0.644
82	0.040	0.712
81	0.002	0.596
80	0.011	0.495
79	0.005	0.257
78	0.000	0.252
Mean	0.012	0.493

Results of the analysis are given in Table 19 and indicate an F0.1 of 0.170 and Fmax of 0.292 with corresponding yields of 1.614 and 1.722 kg, respectively. With the geometric mean (1978-85) recruitment at age 1 of 18620 thousand, these yields would result in long term equilibrium catches of 30000 t and 32000 t at F0.1 and Fmax.

These values of F0.1 and Fmax compare to previously estimated values (Hurley and O'Boyle, 1983) of 0.15 and 0.25, respectively. Serchuk& Wigley (1986) calculated yield per recruit using 1984-85 mean weights at age and estimated F0.1 to be 0.155 and Fmax to be 0.280 with corresponding yields of 1.631 and 1.762 kg, respectively. He used a maturity ogive to determine spawning stock biomass(SSB), at equilibrium yield, and estimates 201000 t and a total biomass of 230000 t at F0.1 and 128000 t SSB and 170000 t total at Fmax.

Discussion

Indices of abundance for this stock are inconsistent. USA research survey results suggest either a continuing decrease in stock numbers (spring) or a steady state at low stock size in recent years (autumn). The two data points available in the Canadian survey are insufficient to assess any trend in abundance. The USA CPUE for both directed and all trips are now less than 50% of the pre-1983 levels with a similar reduction in total catch. Canadian standardized CPUE has remained at relatively high levels with some fluctuation associated with strong recruiting year-classes. Results of SPA indicate high levels of fishing mortality, exceeding F0.1 and Fmax by a factor of 3 or more, in recent years and a decease of 50% in the 3+ biomass.

Recognition of the International boundary has probably changed the exploitation pattern in the commercial fishery with a more pronounced impact on the USA fleet. The historical distribution of catches indicates high catches by both the USA and Canada in the Northeast peak area of the Bank but USA effort in this area was eliminated in 1985 and, assuming a stable stock distribution, a reduction in CPUE could be expected. This reduction would, however, reflect accessibility rather than stock abundance. Canadian CPUE would not have been influenced to the same degree. Distribution of catches of cod in the Canadian 1987 March survey indicate that catch per tow in numbers and weight were higher by a factor of 3-5 in the Canadian part of Subdivision 5Ze (two strata) and accounted for 40% of the total number and biomass. Distribution of catches in the July, 1987 Canadian survey, during the peak of the commercial fishery, were also highly concentrated in the Canadian zone.

Estimated Canadian partial F's (total F times ratio of Canadian to total catch) are given in Table 20. Results indicate mean 3+ fishing mortalities of 0.1 to 0.2 with a maximum value of 0.21 in 1985. The low 1984 value is associated with low levels of effort by the otter trawl fleet. The levels of partial F are close to the F0.1 and Fmax for this stock.

Serchuk & Wigley (1986), using 1978-85 catch at age, report results similar to those of this analysis. Their estimate of terminal F in 1985 was based on the relationship between mean 3+F from SPA and directed effort derived from indices of USA CPUE. The relationship, based on minimization of residuals and correlation coefficient, was optimized at an Ft of 0.82 in 1985. Autumn survey 3+ biomass and SPA 4+ biomass were also correlated and indicated a 1985 Ft of 0.78, although the relationship was not as well defined as that for F and effort.

Management Considerations

Fishing mortality on this stock has exceeded both the F0.1 and the Fmax levels in recent years. However, unilateral imposition of reduced Canadian quotas by Canada based on an F0.1 management strategy may not result in national benefit. The current USA catch exceeds the estimated F0.1 catch and

without a bilateral management strategy by the USA and Canada it is unlikely that reductions in Canadian catches would result in stock rebuilding.

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Table 1. Nominal catches (t, round) of Atlantic cod from Georges Bank and southward (NAFO Division 5Z and Subarea 6), 1960-86.

Year	USA	Canada	USSR	Other (a)	Total
1960	10834	19	-	-	10853
1961	14453	223	55	-	14731
1962	15637	2404	5302	143	23486
1963	14139	7832	5217	1	27189
1964	12325	7108	5428	304	25165
1965	11410	10598	14415	1910	38333
1966	11990	15601	16830	8713	53134
1967	13157	8232	511	14852	36752
1968	15279	9127	1459	17271	43136
1969	16782	5997	646	14514	37939
1970	14899	2583	364	7806	25652
1971	16178	2979	1270	7752	28179
1972	13406	2545	1878	7230	25059
1973	16202	3220	2977	6524	28923
1974	18377	1374	476	7104	27331
1975	16017	1847	2403	4741	25008
1976	14906	2328	933	1759	19926
1977	21138	6173	54	2	27367
1978	26579	8904	-	-	35483
1979	32645	6011	-	-	38656
1980	40053	8094	-	-	48147
1981	33849	8508	-	-	42357
1982	39333	17862	-	-	57195
1983	36756	12172	-	-	48928
1984	32915	5761	-	-	38676
1985	26828	10441	-	-	37269
1986 (b)	17575	8508	-	-	26083

a. Primarily Spain
b. Preliminary

Table 2. Distribution of USA commercial landings (t, round) of Atlantic cod from Georges Bank (5Ze), by gear type, 1965-1986. Data only reflect landings which could be identified by gear type. (from Serchuk and Wigley, 1986 and pers. comm.)

	Landings (t, live)					
Year	Otter Trawl	Line Trawl	Handline	Gillnet	Other Gear	Total
1965	10251	582	505	0	9	11347
1966	10206	787	757	0	19	11769
1967	10915	894	704	0	9	12522
1968	12084	936	524	0	-	13544
1969	13194	1371	387	0	-	14952
1970	11270	1676	404	0	-	13350
1971	12436	2334	230	0	2	15002
1972	10179	2071	217	0	10	12477
1973	12431	2185	206	3	21	14846
1974	14078	2548	11	3	9	16649
1975	12069	2435	84	0	4	14592
1976	12257	1519	153	4	5	13938
1977	18529	912	83	30	22	19576
1978	20862	1569	1180	81	59	23751
1979	26562	2707	860	620	159	30908
1980	32479	1102	-	4491	273	38345
1981	27694	120	584	3515	197	32110
1982	33371	385	624	2935	210	37525
1983	30981	831	441	1812	81	34146
1984	26161	366	753	2573	197	30050
1985	21444	436	284	2482	163	24809
1986	13576	692	305	1679	95	16347

Table 3. Nominal landings of cod by gear and month for Canada(M) in NAFO Division -5Z. (Ot - otter trawl; LL - longline; misc - miscellaneous)

		Month												
Year	Gear	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
78	Ot	167	763	241	26	305	1943	1139	22	220	1733	1625	-	8184
	LL	-	-	-	-	11	193	295	128	74	19	-	-	720
	Misc	-	-	-	1	-	-	1	-	-	-	-	-	2
	Total	167	763	241	27	316	2136	1435	150	294	1752	1625	-	8906
79	Ot	72	301	179	78	74	1635	667	675	661	294	28	7	4671
	LL	-	-	-	5	20	528	333	305	136	11	-	-	1338
	Misc	-	-	1	-	1	-	-	-	-	-	-	-	2
	Total	72	301	180	83	95	2163	1000	980	797	305	28	7	6011
80	Ot	23	86	4	53	110	1374	1594	786	637	617	69	100	5453
	LL	-	-	-	-	208	950	596	496	337	47	-	-	2634
	Misc	-	-	1	2	1	2	1	-	-	-	-	-	7
	Total	23	86	5	55	319	2326	2191	1282	974	664	69	100	8094
81	Ot	2	204	55	8	38	540	1005	743	1024	36	230	98	3983
	LL	-	-	1	2	537	1476	1043	837	286	281	56	5	4524
	Misc	-	-	-	1	-	-	-	-	-	-	-	-	1
	Total	2	204	56	11	575	2016	2048	1580	1310	317	286	103	8508
82	Ot	89	74	-	-	12	882	4283	2112	1509	2361	932	119	12372
	LL	-	11	26	195	773	1036	1386	1083	634	307	34	4	5489
	Misc	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total	89	85	26	195	785	1918	5669	3195	2143	2668	966	123	17862
83	Ot	179	80	9	6	35	2215	1094	2115	957	173	75	11	6949
	LL	-	-	171	147	439	1441	699	576	1304	309	89	-	5175
	Misc	-	-	-	-	-	6	34	3	5	1	-	-	49
	Total	179	80	180	153	474	3662	1827	2694	2266	483	164	11	12173
84	Ot	5	3	13	1	39	272	93	239	61	19	-	-	745
	LL	-	-	167	152	111	1192	1210	1183	605	286	49	-	4955
	Misc	-	-	-	-	-	52	9	-	-	-	-	-	61
	Total	5	3	180	153	150	1516	1312	1422	666	305	49	-	5761
85	Ot	-	2	-	-	165	1172	2561	2431	692	435	4	80	7546
	LL	-	29	54	181	151	414	230	542	647	501	29	29	2807
	Misc	-	1	2	14	15	24	9	19	4	2	1	1	92
	Total	-	32	56	195	331	1606	2800	2992	1343	938	34	110	10441
86	Ot	15	9	-	15	6	2364	3137	477	49	11	4	22	6109
	LL	-	58	81	12	24	146	120	538	606	409	12	-	2006
	Misc	1	2	9	15	10	47	89	76	42	1	-	-	292
	Total	16	69	90	42	40	2557	3346	1091	697	421	16	22	8407

Table 4. Summary of 1986 catch and samples used to estimate catch at age for Canadian landings.

Gear	Month	Weight (t)	Lengths	Ages	Total
OTB	Jan	15			
	Feb	9	313	59	
	Mar	-			
	Apr	15			
	May	6	2487	320	
	Jun	2364			
	Jul	3137			
	Aug	477			
	Sep	49	1875	316	6109 t
	Oct	11			
	Nov	4			
	Dec	22			
Longline	Jan	-			
	Feb	58			
	Mar	81			
	Apr	12			
	May	24			
	Jun	146			
	Jul	120	1084	193	2006 t
	Aug	538			
	Sep	606			
	Oct	409			
	Nov	12			
	Dec	-			
Misc and Nfld		393			393 t
					8508 t

Table 5. Age composition (percent by number) derived from biological samples of Atlantic cod from Georges Bank (5Ze) taken by Canadian vessels, 1975-86

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.06	0.00	0.03	0.09	0.12	0.45	0.00	0.09	0.83
2	1.99	24.64	27.12	9.31	36.71	10.53	1.95	51.57	9.96
3	66.40	23.85	40.19	34.14	25.00	39.87	9.10	21.48	54.59
4	20.60	35.25	7.74	25.35	16.24	25.67	29.46	8.97	16.01
5	6.14	12.29	16.45	6.25	12.15	8.54	30.48	11.93	6.35
6	2.24	2.41	5.31	17.19	2.69	6.07	14.03	3.44	9.53
7	1.68	0.83	1.31	3.77	4.19	2.47	7.71	1.08	1.30
8	0.01	0.02	0.02	0.10	0.02	0.11	0.19	0.02	0.87
9	0.30	0.09	0.73	0.90	0.43	1.83	2.13	0.24	0.39
10+	0.18	0.09	0.54	0.67	0.80	0.91	3.06	0.24	0.17
#samples	29	13	10	17	17	15	7	18	19
#aged	1364	591	536	491	956	601	412	1064	888

Table 6. Removals at age (000's) by Canada and the USA for 1978-86.

	Age Group										
	1	2	3	4	5	6	7	8	9	10+	Total
1978 Cdn	2	65	2162	671	200	73	55	12	10	6	3256
USA	-	331	5731	1636	625	53	288	35	28	8	8735
Total	2	396	7893	2307	825	126	343	47	38	14	11991
1979 Cdn	-	499	483	714	249	49	17	10	2	2	2025
USA	34	1618	572	4107	910	403	59	244	-	45	7992
Total	34	2117	1055	4821	1159	452	76	254	2	47	10017
1980 Cdn	1	704	1043	201	427	138	34	14	19	14	2595
USA	88	3002	4707	286	1888	951	413	76	153	-	11564
Total	89	3706	5750	487	2315	1089	447	90	172	14	14159
1981 Cdn	2	195	715	531	131	360	79	48	19	14	2094
USA	25	3060	3613	1960	101	1026	330	72	109	46	10342
Total	27	3255	4328	2491	232	1386	409	120	128	60	12436
1982 Cdn	7	2047	1394	906	678	150	234	91	24	45	5576
USA	325	7855	2466	1682	1258	117	452	116	50	57	14378
Total	332	9902	3860	2588	1936	267	686	207	74	102	19954
1983 Cdn	15	345	1306	841	280	199	81	118	60	30	3275
USA	81	3542	5557	1244	854	722	85	218	88	62	12453
Total	96	3887	6863	2085	1134	921	166	336	148	92	15728
1984 Cdn	-	21	98	317	328	151	83	22	23	33	1076
USA	81	1281	3305	2961	500	393	386	25	153	82	9167
Total	81	1302	3403	3278	828	544	469	47	176	115	10243
1985 Cdn	4	2144	893	373	496	143	45	39	10	10	4157
USA	130	4280	1539	985	1388	273	173	165	12	86	9031
Total	134	6424	2432	1358	1884	416	218	204	22	96	13188
1986 Cdn	19	232	1270	372	148	222	30	20	9	4	2326
USA	138	1096	3306	434	339	414	58	53	38	27	5903
Total	157	1328	4576	806	487	636	88	73	47	31	8229

Table 7. Mean length-at-age of cod derived from Canadian and USA samples 1978-86. Total weighted by catch in numbers for each country.

Year	Age group 1	2	3	4	5	6	7	8	9	10+ [a]
1978 Cdn	36.4	44.3	53.9	57.9	63.6	74.6	76.0	89.9	86.0	115.0
USA	-	50.2	61.5	69.8	73.7	79.3	89.3	91.3	107.1	115.0
Total	36.4	49.2	59.4	66.3	71.3	76.6	87.2	90.9	101.5	115.0
1979	50.7	53.3	69.1	75.3	80.4	95.9	104.4	99.6	115.0	115.0
	44.7	52.9	61.0	73.9	77.5	88.2	95.3	99.4	-	115.0
	44.7	53.0	64.7	74.1	78.1	89.0	97.3	99.4	115.0	115.0
1980	36.7	49.3	60.1	66.7	78.0	85.7	87.6	105.6	105.2	115.0
	43.9	52.6	61.6	72.4	81.9	86.3	92.9	92.2	91.2	115.0
	41.8	50.7	60.7	69.7	80.8	85.6	92.5	95.6	92.9	115.0
1981	42.2	49.2	58.8	67.8	77.4	85.7	94.5	96.0	97.4	115.0
	44.6	52.3	60.4	68.5	78.4	88.7	93.1	98.2	112.8	115.0
	44.4	52.1	60.1	68.4	77.8	87.9	93.4	97.3	110.5	115.0
1982	36.8	49.8	57.1	69.8	78.6	84.9	95.0	95.8	107.2	115.0
	42.3	51.4	64.4	70.8	79.9	84.1	96.5	99.2	105.5	115.0
	42.2	51.1	61.8	70.4	79.4	84.5	96.0	97.7	106.1	115.0
1983	42.6	50.4	58.4	67.1	77.8	84.8	93.0	99.3	104.4	115.0
	46.3	52.7	61.5	68.1	75.9	84.5	90.7	99.1	101.5	115.0
	45.7	52.5	60.9	67.7	76.4	84.6	91.8	99.2	102.7	115.0
1984	-	50.2	60.4	70.2	76.9	83.5	92.2	99.7	101.4	115.0
	47.2	54.1	61.5	69.8	79.3	86.5	94.8	97.5	102.5	115.0
	47.2	54.0	61.5	69.8	78.3	85.7	94.3	98.5	102.4	115.0
1985	38.7	49.3	55.3	67.9	74.8	83.2	90.1	95.6	98.8	115.0
	45.1	51.8	58.6	72.4	79.0	84.5	91.4	99.4	104.7	115.0
	44.9	51.0	57.4	71.2	77.9	84.1	91.1	98.7	102.0	115.0
1986	39.6	51.7	63.5	71.0	79.7	86.9	92.8	96.2	94.5	115.0
	45.8	52.0	60.1	67.6	81.1	88.2	95.2	98.7	108.2	115.0
	45.1	51.9	61.0	69.2	80.7	87.7	94.4	98.0	105.6	115.0

a) A length of 115 cm was assumed for age 10+

Table 8. Mean weight-at-age for cod derived from Canadian and USA samples, 1978-86. Total weighted by catch in numbers for each country.

		Age group									a
Year		1	2	3	4	5	6	7	8	9	10+
1978	Cdn	0.656	1.206	2.121	2.644	3.540	5.682	6.140	9.268	8.399	15.000
	USA	-	1.298	2.470	3.692	4.473	5.199	7.522	7.924	12.794	15.000
	Total	0.656	1.283	2.374	3.387	4.247	5.479	7.300	8.267	11.637	15.000
1979		-	1.483	1.723	3.691	4.730	5.986	9.586	12.058	10.412	15.000
		0.889	1.522	2.464	4.301	4.974	7.309	9.127	10.264	-	15.000
		0.889	1.513	2.125	4.211	4.922	7.166	9.230	10.335	10.412	15.000
1980		0.572	1.348	2.427	3.241	5.116	6.707	7.148	12.324	12.169	15.000
		0.839	1.490	2.478	3.992	5.792	6.703	8.489	8.648	8.046	15.000
		0.836	1.463	2.469	3.682	5.667	6.704	8.387	9.220	8.501	15.000
1981		0.864	1.368	2.312	3.467	5.113	6.816	9.108	9.575	10.485	15.000
		0.885	1.501	2.360	3.389	5.209	7.339	8.397	9.988	14.884	15.000
		0.883	1.493	2.352	3.406	5.155	7.203	8.534	9.823	14.231	15.000
1982		0.592	1.410	2.128	3.814	5.335	6.656	9.158	9.574	12.941	15.000
		0.767	1.395	2.852	3.845	5.449	6.457	9.473	10.297	12.434	15.000
		0.763	1.398	2.591	3.834	5.409	6.569	9.366	9.979	12.598	15.000
1983		0.885	1.466	2.265	3.371	5.210	6.641	8.593	10.428	11.999	15.000
		0.993	1.497	2.456	3.434	4.703	6.407	7.955	10.280	11.091	15.000
		0.976	1.494	2.420	3.409	4.828	6.458	8.266	10.332	11.459	15.000
1984		-	1.438	2.477	3.841	4.977	6.310	8.541	10.486	11.034	15.000
		1.053	1.638	2.450	3.597	5.308	6.751	8.960	9.710	11.361	15.000
		1.053	1.635	2.451	3.621	5.177	6.629	8.886	10.073	11.318	15.000
1985		0.680	1.391	1.950	3.571	4.742	6.399	8.074	9.664	10.584	15.000
		0.914	1.424	2.157	3.989	5.201	6.398	8.075	10.355	12.107	15.000
		0.907	1.413	2.081	3.874	5.080	6.398	8.075	10.223	11.415	15.000
1986		0.723	1.573	2.897	3.944	5.623	7.208	8.618	9.512	9.996	15.000
		0.957	1.453	2.280	3.413	5.608	7.198	9.066	10.135	13.338	15.000
		0.927	1.474	2.451	3.658	5.613	7.201	8.913	9.965	12.698	15.000

a) a weight of 15.0 kg was assumed for 10+

Table 9a. Stratified mean catch per tow at age (numbers) of Atlantic cod in offshore spring and autumn bottom trawl surveys on Georges Bank a, 1963-1986.b (pers. comm., Dr. F. Serchuk, NMFS, Woods Hole, USA)

	Age											Totals				
Year	0	1	2	3	4	5	6	7	8	9	10+	0+	1+	2+	3+	4+	5+
Spring c																	
1968	.329	.087	1.035	.529	.426	.247	.158	.090	.053	.036	.037	3.027	2.698	2.611	1.576	1.047	.621
1969	.000	.079	.350	1.141	.569	.289	.209	.138	.082	.046	.072	2.975	2.975	2.896	2.546	1.405	.836
1970	.000	.244	.522	.308	.830	.104	.420	.176	.039	.087	.053	2.783	2.785	2.539	2.017	1.709	.879
1971	.000	.133	.525	.322	.143	.375	.091	.225	.195	.051	.112	2.172	2.172	2.039	1.514	1.192	1.049
1972	.036	1.860	1.175	1.695	.327	.076	.208	.078	.141	.074	.080	5.748	5.712	3.852	2.677	.984	.657
1973 d	.036	.334	7.464	1.403	1.628	.273	.201	.227	.032	.130	.249	11.977	11.941	11.607	4.143	2.740	1.112
1974	.000	.286	2.921	3.828	.488	1.284	.282	.065	.165	.022	.112	9.453	9.453	9.167	6.246	2.418	1.930
1975	.000	.041	.242	1.309	1.982	.167	.440	.083	.060	.069	.025	4.418	4.418	4.377	4.135	2.826	.844
1976	.071	.834	1.232	.605	.443	1.008	.105	.168	.023	.000	.035	4.524	4.453	3.619	2.387	1.782	1.339
1977	.000	.018	2.261	.692	.335	.179	.466	.033	.042	.000	.013	4.039	4.039	4.021	1.760	1.068	.733
1978	2.123	.241	.120	3.545	.621	.499	.092	.457	.033	.091	.070	7.892	5.769	5.528	5.408	1.863	1.242
1979	.070	.279	.871	.191	1.226	.347	.150	.056	.093	.008	.014	3.305	3.254	2.956	2.084	1.897	.668
1980	.067	.025	1.452	1.723	.134	.950	.383	.123	.020	.019	.071	4.967	4.890	4.865	3.413	1.690	1.556
1981	.244	1.869	1.555	2.255	1.353	.081	.706	.218	.117	.000	.069	8.467	8.223	6.354	4.799	2.544	1.191
1982 e	.120	.396	2.755	1.141	1.051	.843	.013	.242	.052	.013	.028	6.654	6.534	6.138	5.000	2.242	1.191
1983	.052	.211	1.261	1.954	.491	.447	.276	.035	.123	.000	.087	4.937	4.885	4.674	2.720	1.459	.968
1984	.000	.258	.296	.511	.744	.286	.272	.143	.000	.100	.005	2.615	2.615	2.357	2.061	1.550	.806
1985	.244	.098	2.633	.757	1.058	1.328	.270	.203	.172	.025	.150	6.938	6.694	6.596	3.963	3.206	2.148
1986	.092	.871	.423	1.824	.360	.545	.633	.063	.119	.095	.015	5.040	4.948	4.077	3.654	1.830	1.470
1987 f	(.000)	(1.617)	(.313)	(.871)								(3.255)					
Autumn																	
1963	.012	.461	.499	.590	.575	.227	.209	.112	.066	.009	.044	2.804	2.792	2.331	1.832	1.242	.667
1964	.006	.410	.448	.377	.345	.093	.087	.040	.032	.109	.053	1.910	1.904	1.494	1.046	.669	.324
1965	.111	.833	.640	.45	.310	.107	.115	.072	.052	.015	.015	2.723	2.612	1.779	1.139	.686	.376
1966	.657	1.085	.641	.336	.169	.064	.061	.040	.025	.001	.011	3.084	2.427	1.342	.701	.371	.202
1967	.046	4.869	.855	.335	.260	.085	.085	.035	.033	.008	.045	6.656	6.610	1.741	.886	.551	.291
1968	.045	.201	1.033	.502	.174	.047	.043	.017	.015	.005	.031	2.113	2.068	1.867	.834	.332	.158
1969	.000	.220	.399	.401	.212	.060	.039	.012	.015	.014	.038	1.410	1.410	1.190	.791	.390	.178
1970	.265	1.082	.867	.336	.445	.098	.000	.021	.035	.035	.063	3.247	2.982	1.900	1.033	.697	.252
1971	.256	.386	.405	.250	.193	.385	.117	.027	.057	.000	.048	2.044	1.788	1.402	.997	.747	.554
1972	.607	4.771	.830	1.135	.256	.156	.366	.070	.131	.014	.053	8.389	7.788	3.011	2.181	1.046	.790
1973	.130	1.121	3.891	.758	1.298	.135	.145	.112	.040	.089	.161	7.872	7.742	6.621	2.730	1.972	.682
1974	.296	.262	.419	.975	.105	.073	.066	.000	.041	.000	.000	2.240	1.944	1.682	1.263	.288	.183
1975	1.524	.637	.270	.400	1.080	.072	.100	.000	.000	.000	.024	4.107	2.583	1.946	1.676	1.276	.196
1976	.000	3.941	1.329	.489	.178	.474	.035	.073	.025	.034	.013	6.690	6.690	2.749	1.421	.932	.754
1977	.123	.192	2.778	.570	.204	.141	.321	.006	.022	.000	.063	4.420	4.297	4.105	1.327	.757	.553
1978	.321	1.505	.207	3.392	.782	.272	.134	.279	.041	.024	.011	6.968	6.647	5.142	4.935	1.543	.761
1979	.096	1.314	1.393	.182	1.389	.240	.146	.029	.093	.006	.018	4.826	4.730	3.416	2.023	1.841	.532
1980	.227	.664	.458	.628	.062	.204	.043	.054	.020	.000	.000	2.360	2.133	1.469	1.011	.383	.321
1981	.212	2.960	1.826	1.265	.478	.044	.470	.046	.052	.015	.067	7.335	7.123	4.263	2.437	1.172	.694
1982	.205	.561	1.342	.141	.844	.062	.000	.010	.000	.000	.014	2.379	2.174	1.613	.271	.130	.086
1983	.661	.415	.655	.510	.035	.030	.002	.000	.000	.000	.015	2.331	1.670	1.255	.600	.090	.055
1984	.119	1.600	.065	.568	.558	.011	.040	.025	.004	.025	.028	3.043	2.924	1.324	1.259	.691	.133
1985	1.084	.220	.803	.103	.115	.101	.000	.000	.004	.000	.000	2.430	1.346	1.126	.323	.220	.105
1986	.096	2.280	.153	.382	.010	.061	.090	.016	.000	.008	.028	3.124	3.028	.748	.595	.213	.203

a. Spring and autumn cover USA strata 13-25
b. Catch per tow at age for 1963-69 obtained by applying 1970-81 age-length keys to stratified mean catch per tow at length distributions from each survey.
c. Spring surveys during 1973-81 were accomplished with a "Yankee 41" trawl. In all other years, spring surveys were accomplished with a "Yankee 36" trawl. No adjustments have been made for these gear differences.
d. Excludes unusually high catch of 1894 cod (2558 kg) at Station 230 (Strata tow 20-4)
e. Excludes unusually high catch of 1032 cod (4096 kg) at Station 323 (Strata tow 16-7)
f. Preliminary estimate from length distribution

Table 9b. Catch per tow in numbers for Canadian March survey of Subdivision 5Ze using a Western IIa trawl.

	Age											Totals				
Year	0	1	2	3	4	5	6	7	8	9	10+	0+	1+	2+	3+	4+	5+
1986	.000	.540	2.210	2.580	.330	.550	.370	.210	.040	.070	.040	6.940	6.940	6.400	4.190	1.610	1.280
1987	.000	.260	2.120	.920	1.080	.330	.120	.210	.070	.030	.060	5.200	5.200	4.940	2.820	1.900	0.820

Table 10. Stratified mean catch per tow in numbers and weight (kg) for Atlantic cod from USA offshore spring, summer and autumn bottom trawl surveys (Strata 13-25) 1963-86. Results of Canadian survey using Western IIa trawl are included for information.

	Spring a		Summer b		Autumn	
Year	Nos	Wgt (kg)	Nos	Wgt (kg)	Nos	Wgt (kg)
1963	-	-	-	-	2.80	11.0
1964	-	-	-	-	1.91	7.1
1965	-	-	-	-	2.72	7.2
1966	-	-	-	-	3.09	5.0
1967	-	-	-	-	6.66	8.3
1968	3.03	7.8	-	-	2.12	5.3
1969	2.97	11.0	-	-	1.41	4.9
1970	2.78	9.7	-	-	3.25	7.8
1971	2.17	8.8	-	-	2.04	6.1
1972	5.74	11.7	-	-	8.39	14.2
1973	11.98e	24.5e	-	-	7.87	19.1
1974	9.45	22.5	-	-	2.24	5.1
1975	4.42	16.1	-	-	4.11	8.7
1976	4.52	11.5	-	-	6.68	10.9
1977	4.04	9.5	7.87	17.6	4.42	11.5
1978 c	7.89	19.3	3.62	10.7	6.97	21.5
1979	3.30	10.4	5.25	12.3	4.82	15.2
1980 d	4.96	15.3	10.39	15.0	2.36	6.2
1981	8.47	24.0	7.00	10.2	7.33	17.5
1982	6.65e	14.2e	-	-	2.38	4.3
1983	4.94	14.8	-	-	2.33	4.0
1984	2.61	9.5	-	-	3.04	6.3
1985	6.94	21.5	-	-	2.43	3.5
1986	5.04	16.7	-	-	3.12	4.7
1987	3.25	10.3	-	-	-	-
1986 Cdn	6.94	16.1	-	-	-	-
1987 Cdn	5.20	13.1	-	-	-	-

a. Spring surveys, 1973-80, were accomplished with "41 Yankee" trawl and with "36 Yankee" trawl in other years. No adjustment in catch per tow has been made for these gear differences.
b. Summer surveys only include Strata 13, 16, 19-25
c. Summer survey in 1978 only sampled Strata 13, 16, 19-20, 23-25
d. Summer survey in 1981 only sampled Strata 13, 16, 19-21, 23, 25
e. Excludes one unusually high catch of cod.
Cdn Canadian March stratified random survey of Division 5Ze

Table 11. Catch rate index for cod in NAFO Division 5Z, standardized to Can-M OTB2-5 and June. The standardized effort index was calculated using the mean catch rate and catch.

Year	CPUE	Catch	Effort	Ln CPUE
67	0.505	36752	72842	-0.76700
68	0.565	43136	76330	-0.65250
69	0.478	37939	79386	-0.82120
70	0.342	25652	75067	-1.15380
71	0.328	28179	85833	-1.19550
72	0.359	25059	69761	-1.09920
73	0.384	28923	75233	-1.03600
74	0.310	27331	88158	-1.21090
75	0.399	25008	62672	-0.98990
76	0.292	19926	68147	-1.30560
77	0.901	27367	30386	-0.18370
78	0.897	35483	39577	-0.19180
79	0.727	38656	53150	-0.40660
80	0.571	48147	84274	-0.64160
81	0.754	42357	56180	-0.36160
82	0.818	57195	69934	-0.28410
83	0.516	48928	94885	-0.74490
84	0.471	37676	82111	-0.82400
85	0.660	37269	56510	-0.49650
86	0.600	26083	43476	-0.58970

Gear	ln power
OTB1-4	.000
OTB2-2	.073
OTB2-4	.157
OTB2-3	.242
OTB2-5	.416

Month	ln power
Nov	-0.410
Sep	-0.202
Oct	-0.178
Aug	-0.162
Dec	-0.107
May	-0.062
Feb	-0.051
Jul	-0.016
Jun	-0.000
Jan	0.115
Apr	0.308
Mar	0.574

Regression of Multiplicative model

Multiple r-squared 0.590

Analysis of Variance

Source	DF	Sum Squares	Mean Squares	f-value
Intercept	1	2.980 E2	2.980 E2	
Regression	34	7.287 E1	2.143 E0	12.249
Gear	4	8.794 E0	2.199 E0	12.566
Month	11	6.313 E0	5.739 E-1	3.280
Year	19	3.061 E1	1.611 E0	9.207
Residuals	290	5.074 E1	1.750 E-1	
Total	325	4.216 E2		

Table 12. USA commercial landings and landings per day fished for otter trawl trips catching cod from Georges Bank (5Ze), 1965-86. (from Serchuk and Wigley, 1986)

Year	All Trips		50% Trips	
	Landings	t/day Fished	Landings	t/day Fished
1965	10039 t	0.74 *	1190	4.79 *
1966	9871	0.73	1368	4.74
1967	10248	0.76	2371	4.22
1968	12085	1.05	3123	3.97
1969	13194	1.26	4160	3.72
1970	11270	1.18	3598	3.96
1971	12430	1.22	4512	3.84
1972	10180	1.07	4168	3.53
1973	12431	1.45	6304	5.01
1974	14073	1.49	7865	4.39
1975	12065	1.33	6052	4.29
1976	12251	1.55	6488	4.32
1977	18523	1.78	9996	5.70
1978	20847	1.94	9827	4.81
1979	26449	2.10	14596	4.17
1980	32446	2.16	17987	4.39
1981	27613	1.89	14492	3.97
1982	33314	2.18	23561	4.45
1983	30958	2.00	21245	4.25
1984	26157	1.42	15916	2.98
1985	21437	1.15	14962	2.26
1986		0.96		2.15

* mean of the weighted, on catch, values for TC 2,3 and 4

Table 13. Comparison of CPUE indices for USA and Canadian otter trawlers for 1978-86. Indices standardized to the mean for the time period. The combined index derived from USA and Canadian CPUE weighted by catch. Catch rates for USA TC3 and 4 vessels fishing on the Northeast peak for July-September.

Year	Canadian Standardized	USA directed Sub. 5Ze	USA directed TC 3 NE Peak	USA directed TC 4 NE Peak	Weighted Combined
1978	1.342	1.295	1.387	-	1.331
1979	1.088	1.123	0.834	1.017	1.093
1980	0.855	1.182	0.957	1.172	0.910
1981	1.128	1.069	0.902	1.088	1.116
1982	1.224	1.198	1.332	1.193	1.216
1983	0.772	1.144	0.947	0.970	0.865
1984	0.705	0.802	0.641	0.561	0.719
1985	0.988	0.609	-	-	0.881
1986	0.898	0.579	-	-	0.794

Table 14. Calculation of weighted relative effort(RE)* using USA and Canadian CPUE and catch.

Year	USA			Relative	Canada			Relative	Weighted*
	CPUE	Catch	Effort	Effort	CPUE	Catch	Effort	Effort	Effort
78	4.81	26579	5526	.625	.897	8904	9926	.680	.639
79	4.17	32645	7829	.885	.727	6011	8268	.567	.836
80	4.39	40053	9124	1.032	.571	8094	14175	.972	1.022
81	3.97	33849	8526	.964	.754	8508	11284	.773	.926
82	4.45	39333	8839	1.000	.818	17862	21836	1.497	1.155
83	4.25	36756	8648	.978	.516	12172	23589	1.617	1.137
84	2.98	32915	11045	1.249	.471	5761	12231	.838	1.188
85	2.26	26828	11871	1.343	.660	10441	15820	1.084	1.270
86	2.15	17575	8174	.924	.600	8508	14180	.972	.940

* (USA RE X USA catch) + (Canadian RE X Canadian catch)/Total catch

Table 15. Recruitment indices for Atlantic cod calculated from USA offshore autumn bottom trawl survey from Georges Bank during 1963-86. Catch per tow normalized to mean of the 1963-86 values.

Year-class	Age Group	
	0 + 1	1 + 2
1962	-	0.416
1963	0.175	0.500
1964	0.324	0.660
1965	0.598	0.870
1966	2.958	2.390
1967	0.154	0.291
1968	0.160	0.551
1969	0.407	0.626
1970	0.599	0.594
1971	2.234	3.898
1972	1.462	0.648
1973	0.321	0.244
1974	0.747	0.957
1975	4.094	2.984
1976	0.072	0.184
1977	0.777	1.319
1978	1.044	0.742
1979	0.414	1.237
1980	1.465	1.801
1981	0.574	0.565
1982	0.507	0.191
1983	1.735	1.036
1984	0.287	0.165
1985	2.715	-

Table 16. Estimates of instantaneous total mortality (Z) and fishing mortality (F) with instantaneous mortality (M) assumed to be 0.20 for different time periods, derived from USA and Canadian offshore spring and autumn bottom trawl survey data.

	Spring a		Autumn b	
Time Period	Z	F	Z	F
1964 - 67	-	-	0.73	0.53
1968 - 72 c	0.34	0.14	0.49	0.29
1973 - 76	0.70	0.50	0.56	0.36
1977 - 80	0.34	0.14	0.76	0.56
1982 - 86	0.45	0.25	1.29	1.09
1984 - 86	0.27	0.07	0.66	0.46
1986 - 87 d	0.68	0.48	-	-
1986 - 87 e	0.79	0.59	-	-
1986 - 87 f	0.82	0.62	-	-

a. ln ((age 4+ for years i to j) / (age 5+ for years i+1 to j+1))
b. ln ((age 3+ for years i to j) / (age 4+ for years i+1 to j+1))
c. excludes spring 1972-73 (4+/5+) since these gave negative Z value
d. Canadian survey ln((4+ in '86)/(5+ in '87))
e. Canadian survey ln((3+ in '86)/(4+ in '87))
f. Canadian survey ln((2+ in '86)/(3+ in '87))

Table 17. Summary of regression analysis of mean 3+ F from SPA and calculated directed effort from USA and Canadian CPUE. (SR = sum residuals for last 3 years; SSR = sum of squares of residuals for last three years).

	Terminal Fishing Mortality							
	0.25	0.30	0.35	0.40	0.45	0.50	0.60	0.70
a) Mean 3+ F regressed on directed effort from Canadian CPUE								
Rsq	.554	.576*	.519	.414	.305	-	-	-
Intercept	.255*	.249	.275	.304	.332	-	-	-
84 Resid	-.007*	.010	.025	.037	.049	-	-	-
85	.037*	.075	.109	.139	.166	-	-	-
86	-.144	-.087	-.058	-.029	-.001*	-	-	-
SR	-.124	-.002*	.076	.147	.216	-	-	-
SSR	.014	.013*	.016	.022	.030	-	-	-
b) Mean 3+ F regressed on directed effort from USA CPUE								
Rsq	-	.214	-	.620	-	.836	.870*	.823
Intercept	-	.285	-	.183	-	.096	.023*	-.039
84 Resid	-	.046	-	.051	-	.050	.043	-.034*
85	-	-.021	-	-.014	-	-.009	-.005	-.003*
86	-	-.161	-	-.105	-	-.040	.029*	.012
SR	-	-.136	-	-.068	-	.001*	.067	.065
SSR	-	.026	-	.014	-	.004	.003*	.012
c) Mean 3+ F regressed on relative effort from USA and Canadian CPUE								
Rsq	-	.530	.731	.852	-	.869*	.749	.615
Intercept	-	.294*	.351	.399	-	.480	.539	.585
84 Resid	-	.015	.018	.018	-	.017	.012	.005*
85		-.026	-.006*	.013	-	.047	.078	.104
86		-.132	-.097	-.061	-	.015*	.093	.173
SR	-	-.143	-.085	-.030*	-	.079	.183	.282
SSR		.018	.010	.004	-	.003*	.015	.041

Table 18. Results of SPA with Ft set to 0.7 and partial recruitment of 0.006, 0.357, 1 1 1... in 1986.

Population Numbers

	1978	1979	1980	1981	1982	1983	1984	1985	1986	
1 -	28024	23990	18974	39692	16307	9055	23551	8205	38578	0
2 -	4633	22943	19611	15454	32473	13051	7327	19209	6597	31443
3 -	25731	3435	16868	12702	9708	17627	7168	4821	9914	4206
4 -	8193	13925	1858	8608	6484	4455	8222	2790	1746	4031
5 -	2915	4621	7039	1080	4794	2967	1761	3765	1055	710
6 -	1108	1640	2734	3668	675	2173	1131	693	1378	429
7 -	1471	793	934	1253	1749	311	946	434	191	560
8 -	60	894	581	360	656	811	104	350	158	78
9 -	129	6	502	394	186	350	360	43	102	64
10+-	48	150	41	185	231	217	235	187	67	69
1+	72312	72397	69141	83397	73262	51017	50806	40496	59786	41590
2+	44288	48407	50167	43705	56955	41962	27254	32290	21208	41590
3+	39655	25464	30556	28251	24482	28911	19928	13082	14611	10147
4+	13923	22029	13688	15548	14775	11284	12759	8261	4697	5941

Mean Population Biomass (t)

	1978	1979	1980	1981	1982	1983	1984	1985	1986
1 -	18140	19315	14345	31754	11154	7965	22436	6686	32342
2 -	5207	29882	23273	18452	33969	14667	9788	19857	7830
3 -	44343	5453	30312	21749	17474	29844	11371	6301	16023
4 -	21550	42504	5281	22192	17247	9895	20662	6911	4212
5 -	9582	17696	29309	4442	17915	9192	5927	12064	3905
6 -	5432	8985	12727	18665	3084	9526	4825	2490	6543
7 -	8560	6288	5049	7874	11434	1563	5324	2207	1120
8 -	202	7021	4436	2589	4860	5741	695	2054	1039
9 -	1151	50	3111	4140	1636	2735	2621	306	853
10+-	538	1679	447	2045	2421	2226	2270	1756	664
1+	117005	138873	128290	133903	121193	93353	85920	60632	74530
2+	98865	119557	113945	102149	110039	85389	63484	53946	42188
3+	93658	89676	90672	83697	76070	70721	53696	34089	34358
4+	47015	84223	60360	61948	58596	40878	42325	27789	18336

Fishing Mortality

	1978	1979	1980	1981	1982	1983	1984	1985	1986
1 -	0.000	0.002	0.005	0.001	0.023	0.012	0.004	0.018	0.004
2 -	0.099	0.108	0.234	0.265	0.411	0.399	0.219	0.461	0.250
3 -	0.414	0.415	0.473	0.472	0.579	0.563	0.744	0.815	0.700
4 -	0.373	0.482	0.342	0.385	0.582	0.728	0.581	0.772	0.700
5 -	0.375	0.325	0.452	0.271	0.591	0.764	0.733	0.805	0.700
6 -	0.134	0.363	0.580	0.541	0.575	0.632	0.758	1.090	0.700
7 -	0.298	0.112	0.753	0.447	0.568	0.893	0.794	0.810	0.700
8 -	2.035	0.377	0.188	0.459	0.429	0.612	0.690	1.034	0.700
9 -	0.390	0.420	0.470	0.440	0.570	0.620	0.760	0.820	0.700
10+-	0.390	0.420	0.470	0.440	0.570	0.620	0.760	0.820	0.700
3+	0.393	0.421	0.473	0.445	0.577	0.620	0.679	0.824	0.700

Table 19. Yield per recruit analysis for 5Ze cod with 1978-86 mean weight at age (ages 1-9) and derived from growth curve (ages 10-15) and partial recruitment from converged part of fishing mortality matrix.

Age	Weight at age	Partial recruitment
1	0.877	0.011
2	1.463	0.493
3	2.368	1.000
4	3.676	1.000
5	5.122	1.000
6	6.645	1.000
7	8.551	1.000
8	9.802	1.000
9	11.585	1.000
10	12.557	1.000
11	14.027	1.000
12	15.394	1.000
13	16.652	1.000
14	17.800	1.000
15	18.839	1.000

natural mortality rate > 0.2
F0.1 computed as 0.1699 at y/r of 1.6136
Fmax computed as 0.2917 at y/r of 1.7222

Yield per recruit analysis

	fishing mortality	catch number	yield kg	avg. weight kg	yield per unit effort
	0.1000	0.245	1.327	5.418	1.397
F0.1==	0.1699	0.342	1.614	4.724	1.000
	0.2000	0.373	1.669	4.476	0.879
Fmax==	0.2917	0.445	1.722	3.871	0.622
	0.3000	0.450	1.722	3.825	0.604
	0.4000	0.502	1.691	3.369	0.445
	0.5000	0.539	1.639	3.041	0.345
	0.6000	0.567	1.586	2.797	0.278
	0.7000	0.589	1.538	2.609	0.231
	0.8000	0.608	1.496	2.462	0.197
	0.9000	0.623	1.459	2.344	0.171
	1.0000	0.635	1.427	2.246	0.150
	1.1000	0.646	1.400	2.165	0.134
	1.2000	0.656	1.375	2.097	0.121
	1.3000	0.664	1.354	2.038	0.110
	1.4000	0.672	1.335	1.987	0.100
	1.5000	0.679	1.319	1.943	0.093

Table 20. Ratio of Canadian to total catch at age and Canadian partial fishing mortality, 1978-86.

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	1.000	0.000	0.011	0.074	0.021	0.156	0.000	0.030	0.121
2	0.164	0.236	0.190	0.060	0.207	0.089	0.016	0.334	0.175
3	0.274	0.458	0.181	0.165	0.361	0.190	0.029	0.367	0.278
4	0.291	0.148	0.413	0.213	0.350	0.403	0.097	0.275	0.462
5	0.242	0.215	0.184	0.565	0.350	0.195	0.396	0.263	0.304
6	0.579	0.108	0.127	0.260	0.562	0.216	0.278	0.344	0.349
7	0.160	0.224	0.076	0.193	0.341	0.488	0.177	0.206	0.341
8	0.255	0.039	0.156	0.400	0.440	0.351	4.723	0.191	0.274
9	0.263	1.000	0.110	0.148	0.324	0.405	0.131	0.455	0.191
10+	0.429	0.043	1.000	0.233	0.489	0.326	0.287	0.104	0.129

b) Canadian partial F (total F times catch at age ratio)

1	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.001	0.001
2	0.016	0.025	0.045	0.016	0.085	0.035	0.004	0.154	0.044
3	0.113	0.190	0.086	0.078	0.209	0.107	0.021	0.299	0.194
4	0.108	0.071	0.141	0.082	0.204	0.294	0.056	0.212	0.323
5	0.091	0.070	0.083	0.153	0.207	0.149	0.290	0.212	0.213
6	0.078	0.039	0.074	0.140	0.323	0.137	0.210	0.375	0.244
7	0.048	0.025	0.057	0.086	0.194	0.436	0.141	0.167	0.239
8	0.520	0.015	0.029	0.184	0.189	0.215	0.323	0.198	0.192
9	0.103	0.420	0.052	0.065	0.185	0.251	0.099	0.373	0.134
10+	0.167	0.018	0.470	0.103	0.279	0.202	0.218	0.085	0.090

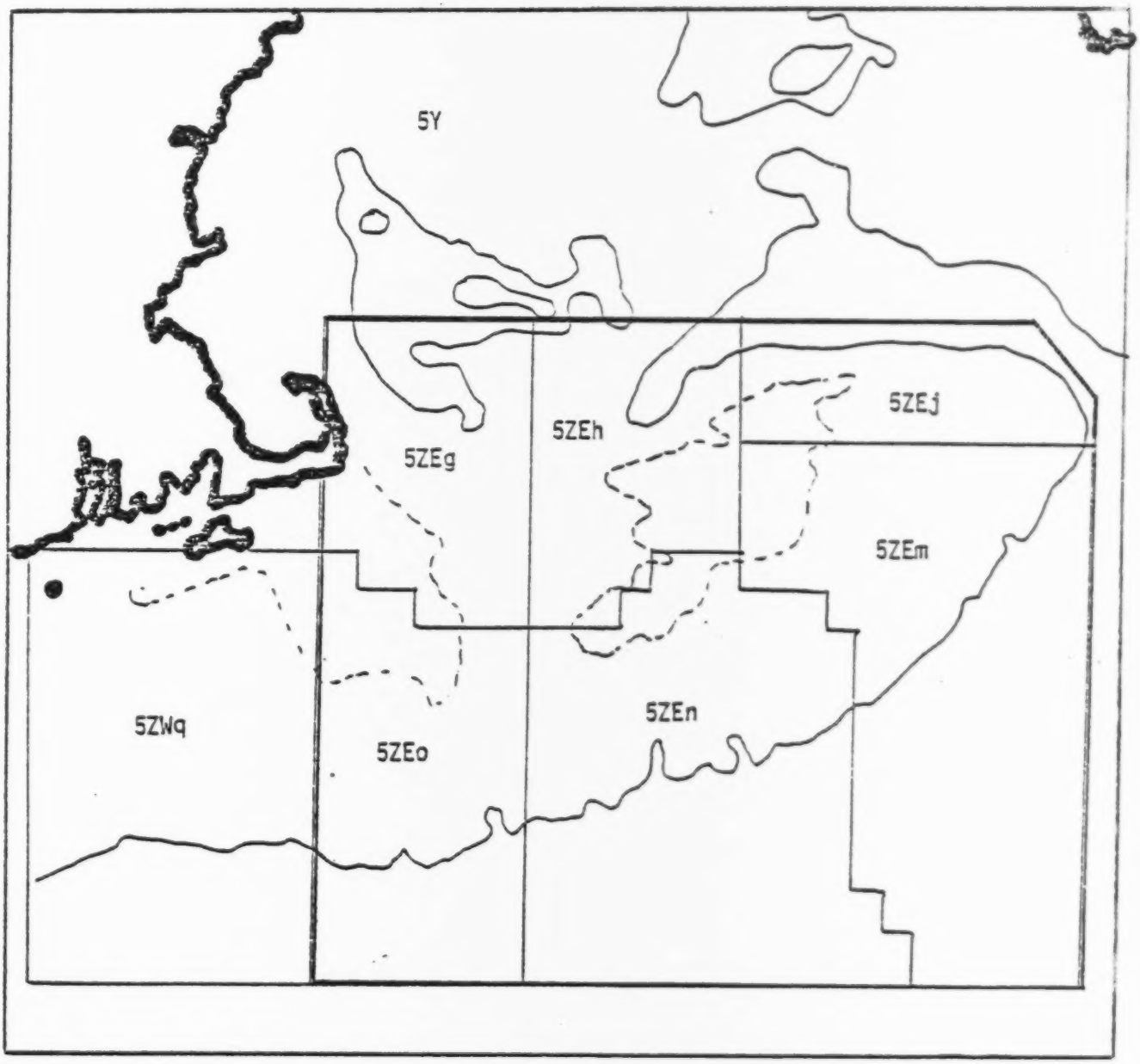


Figure 1. NAFO statistical areas for Georges Bank

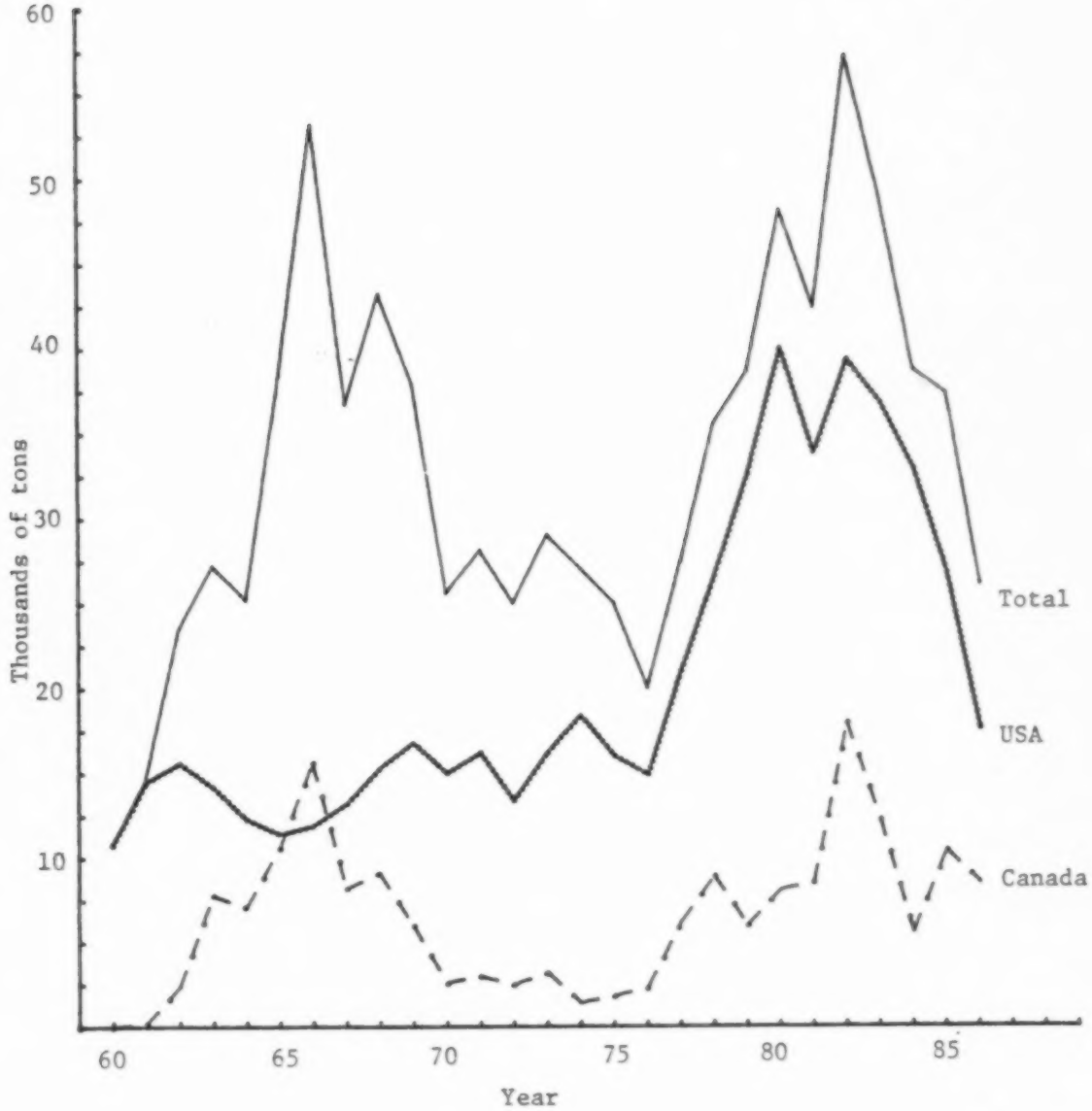


Figure 2. Reported landings of cod by Canada and the USA from NAFO Division 5Z and Subarea 6, 1960-86.

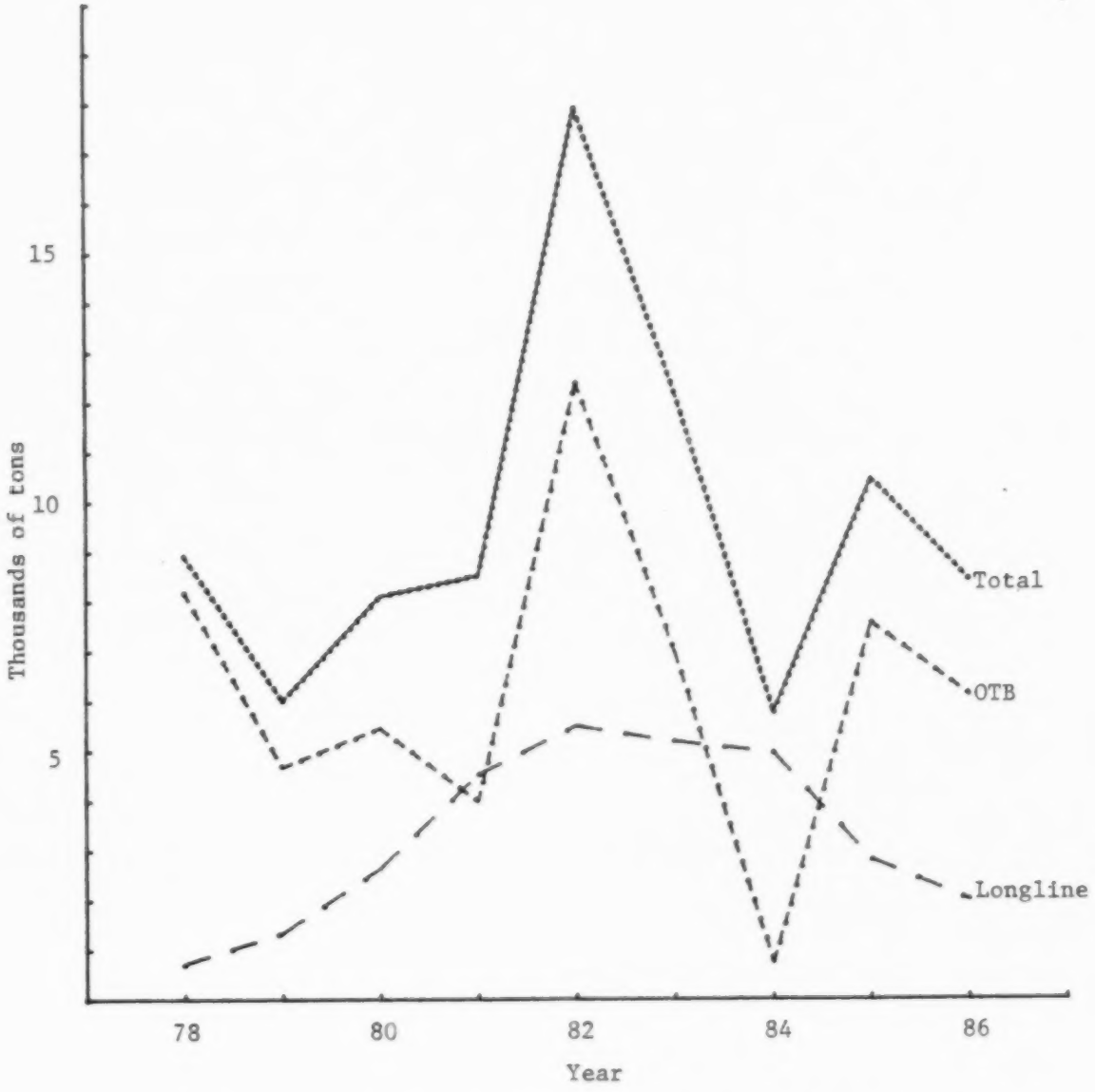


Figure 3. Canadian reported landings of cod in Subdivision 5Ze by gear type for 1978-86.

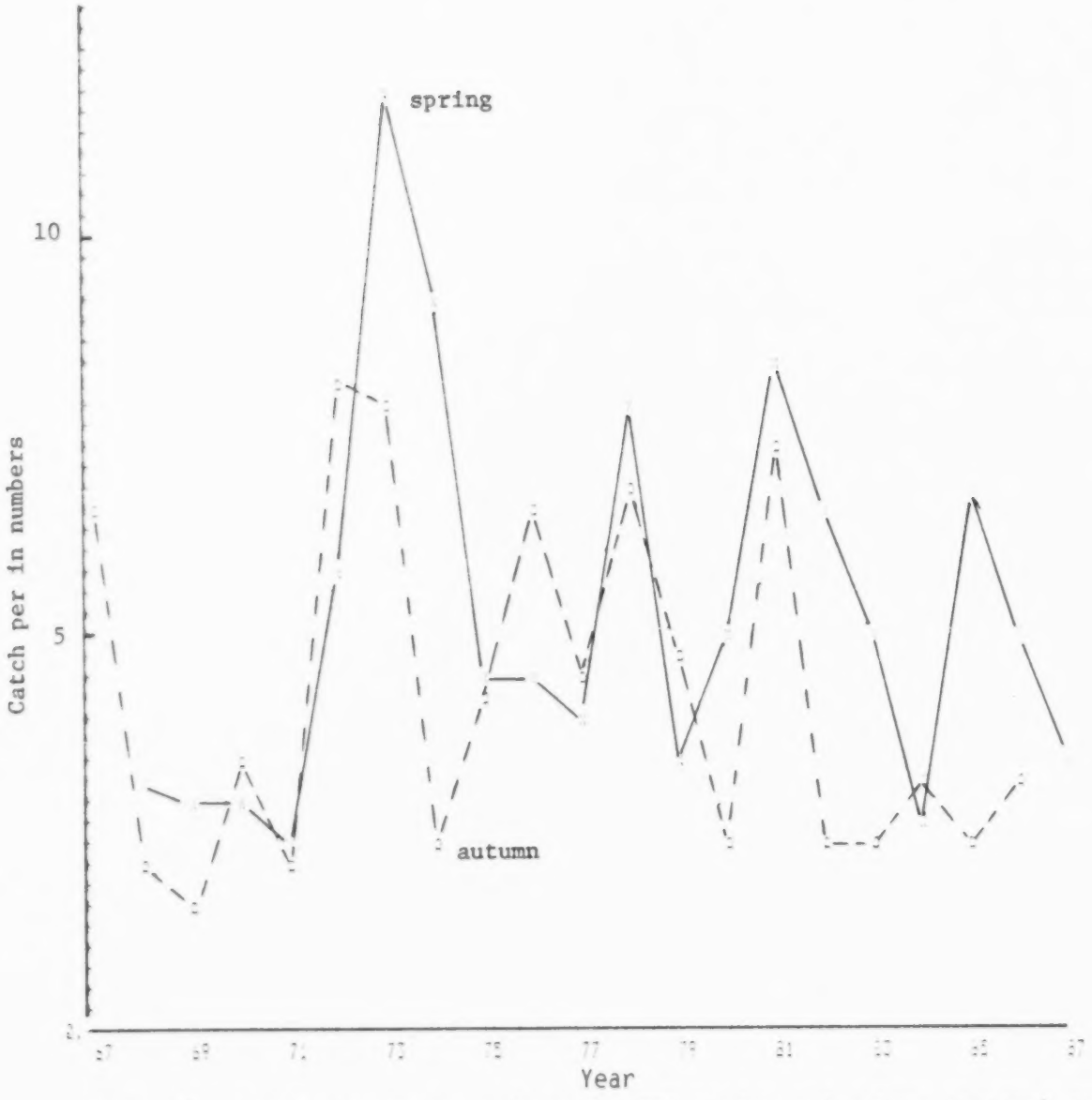


Figure 4 . Catch per tow in numbers for USA spring and autumn research surveys.

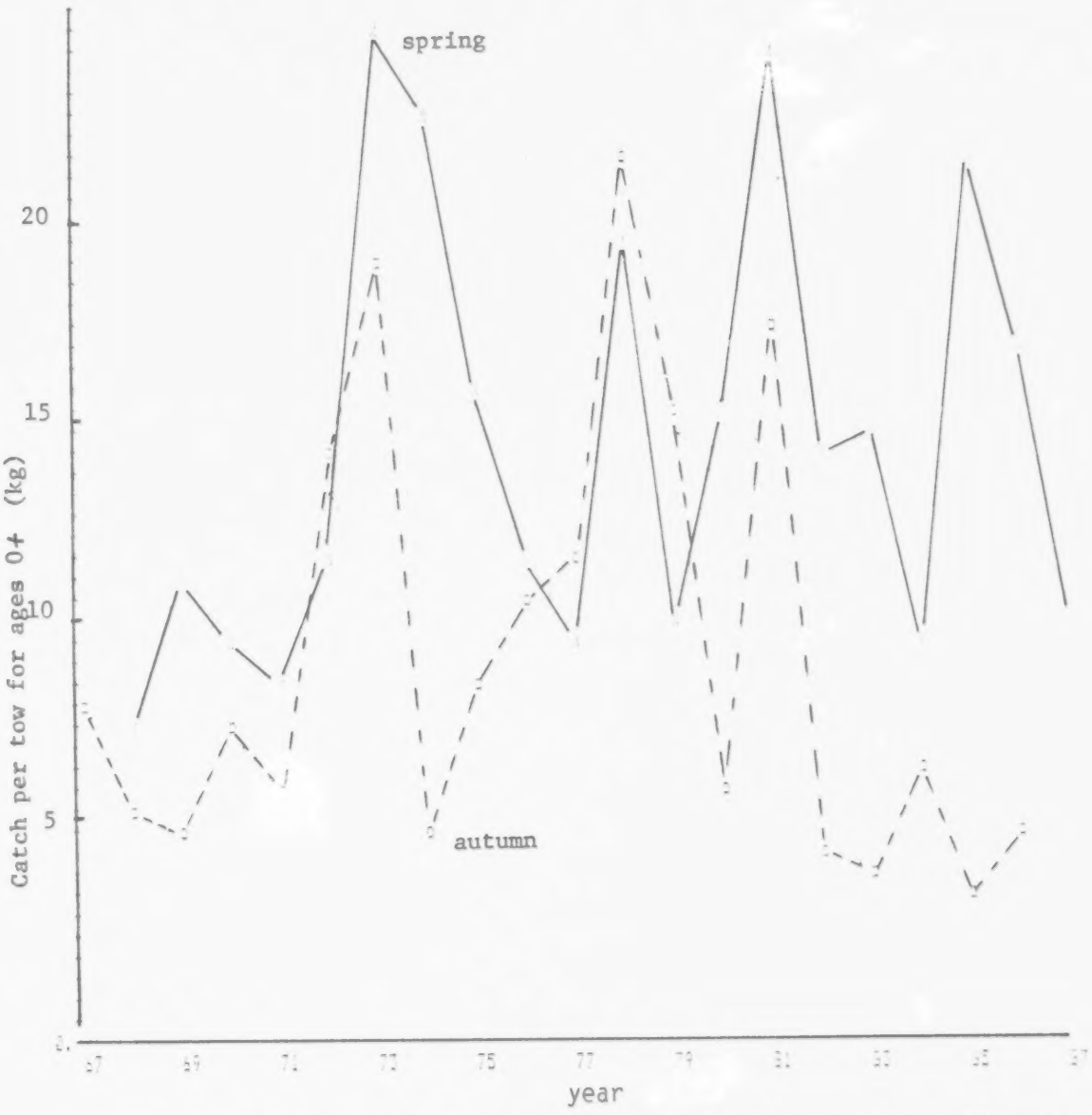


Figure 5. Catch per tow in kg for USA spring and autumn research surveys.

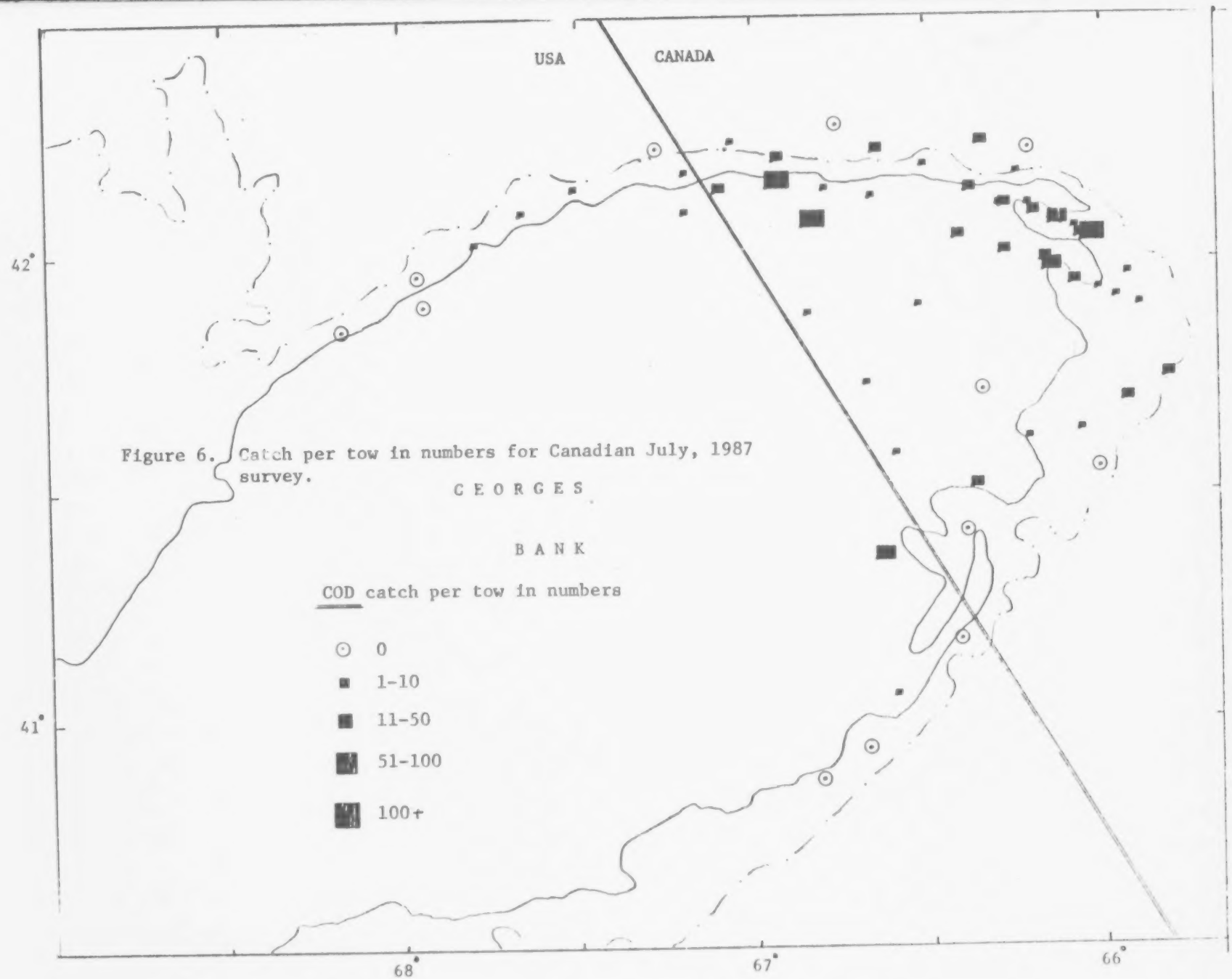


Figure 6. Catch per tow in numbers for Canadian July, 1987 survey.

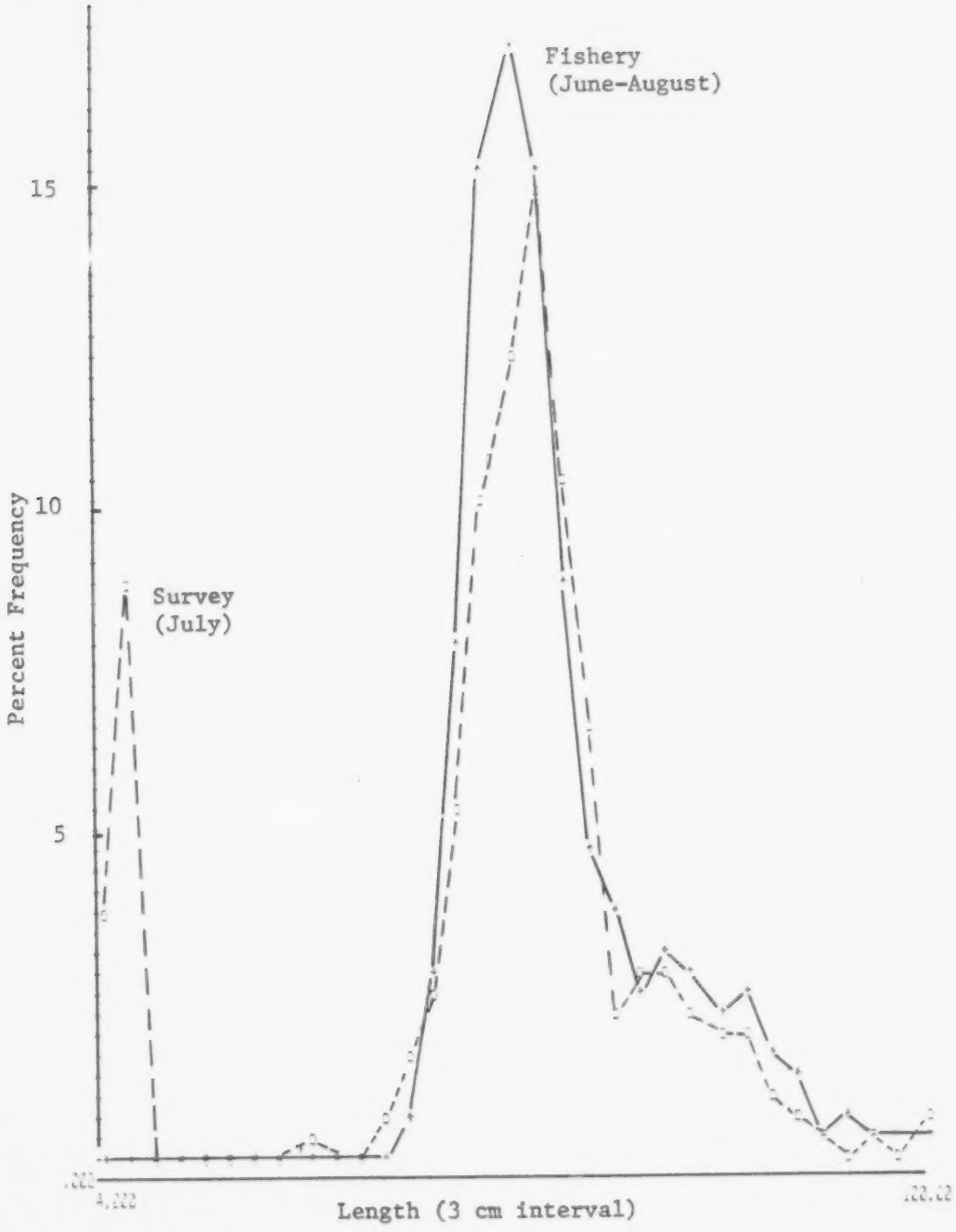


Figure 7. Comparison of percent length frequency distribution of cod from commercial landings and research survey in July, 1987.

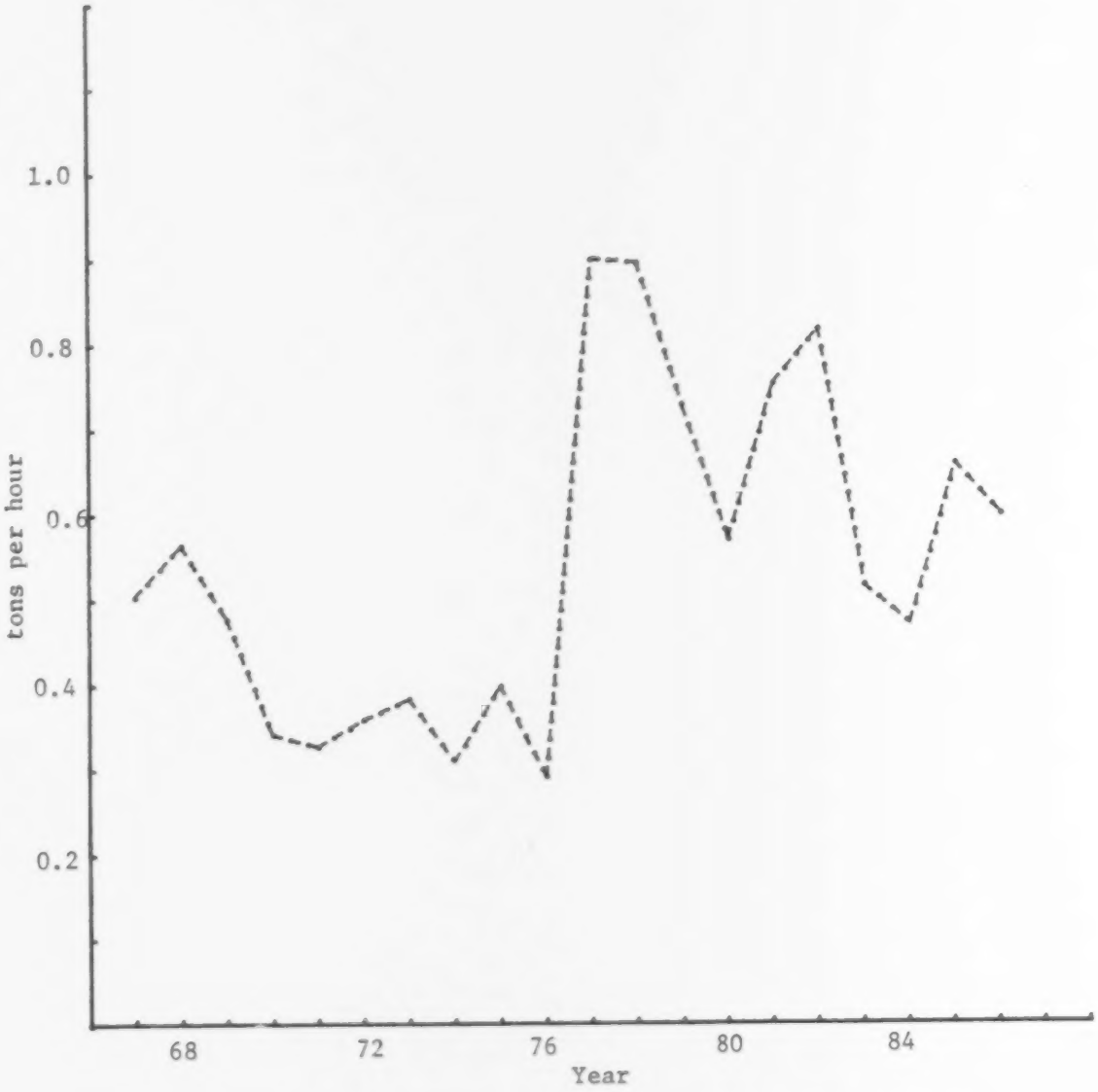


Figure 8. Standardized Canadian CPUE (t/hour) for OTB, 1967-86.

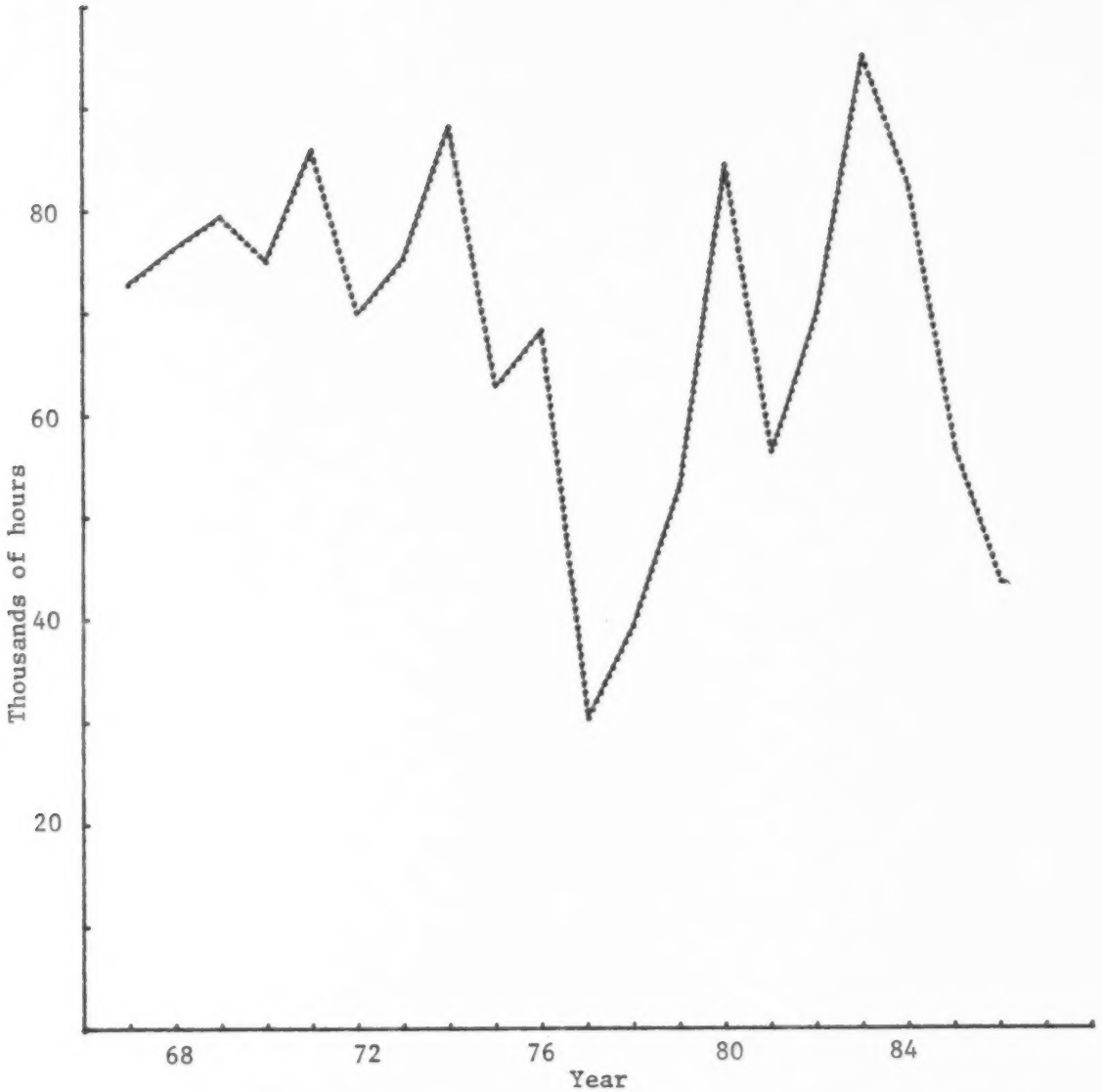


Figure 9. Directed effort (hours) derived from Canadian standardized CPUE for 1967-86.

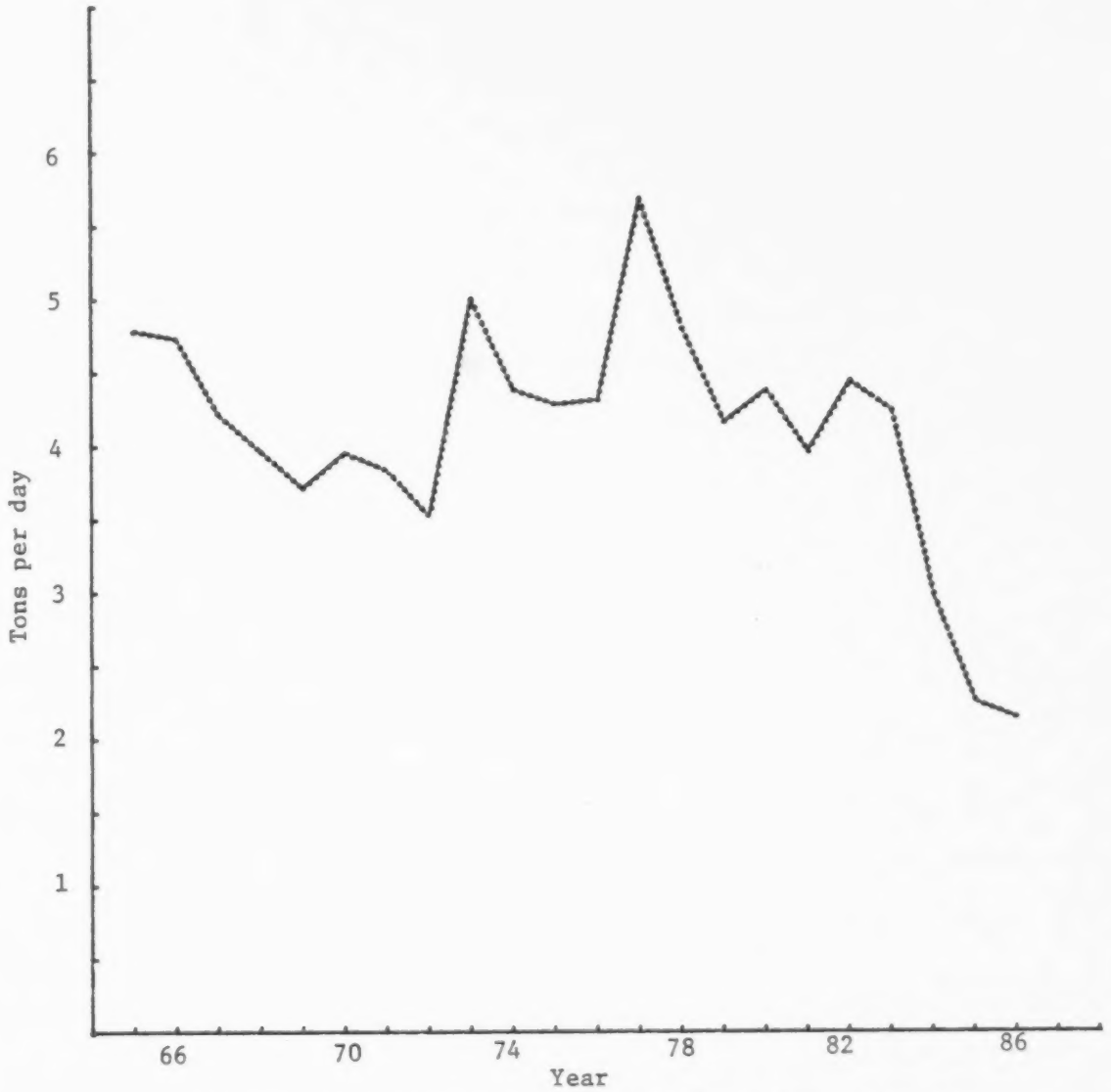


Figure 10. USA otter trawler CPUE (t/day) for directed trips.

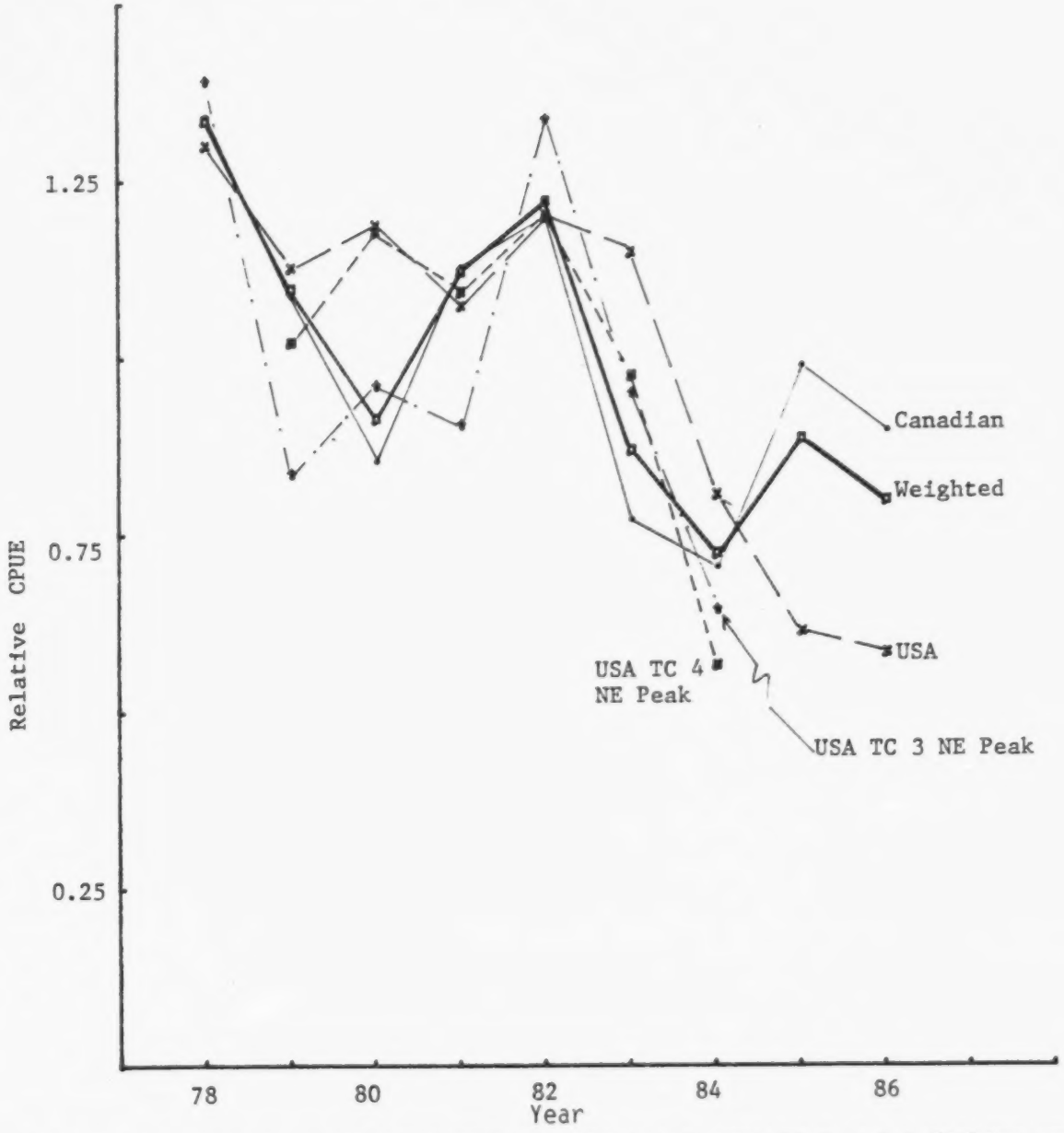


Figure 11. Trends in relative CPUE for USA total, USA TC 3 and 4 fishing on NE Peak of Georges Bank and Canadian standardized, 1978-86.

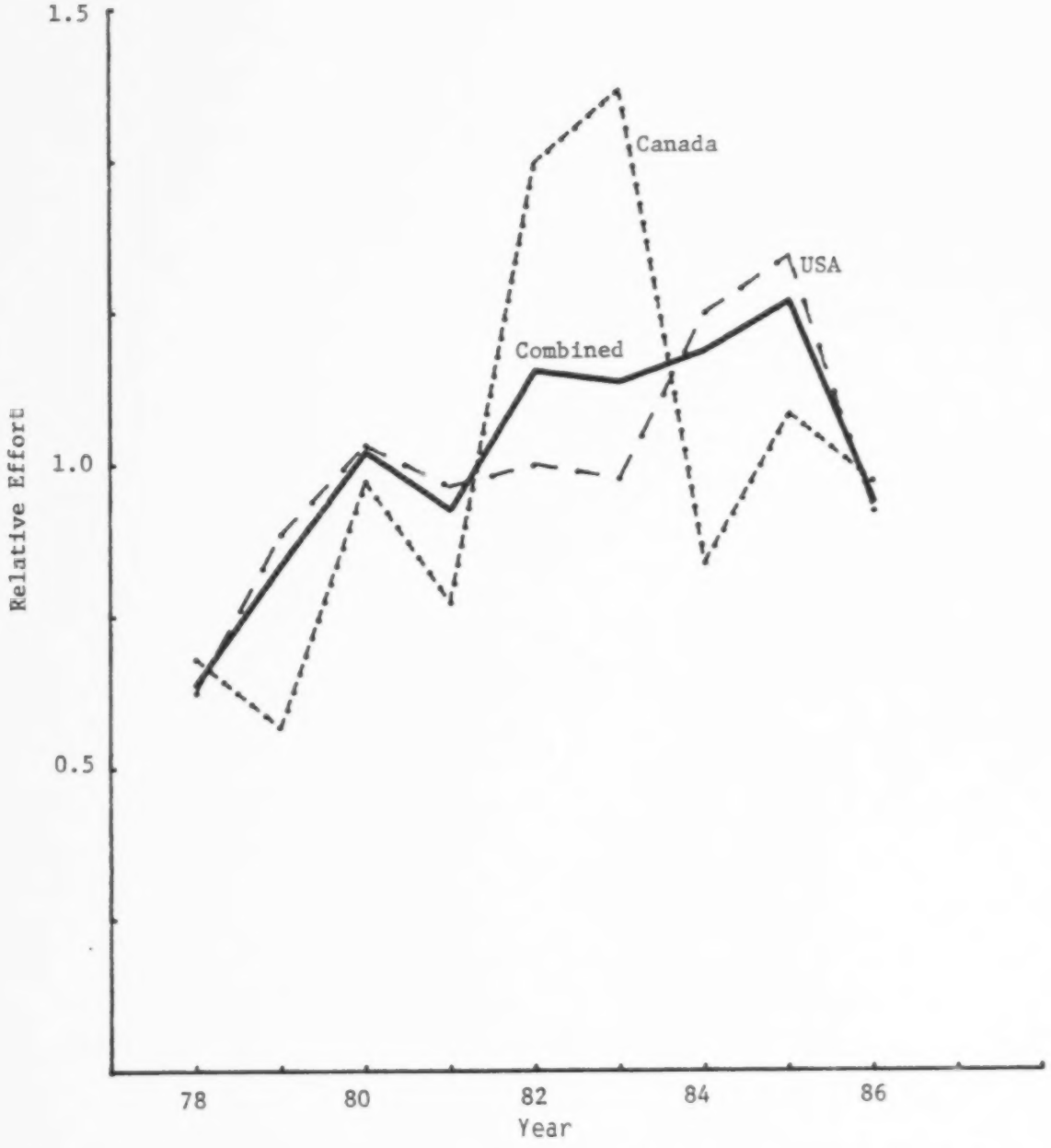


Figure 12. Comparison of directed effort derived from USA, Canadian and weighted CPUE, 1978-86.

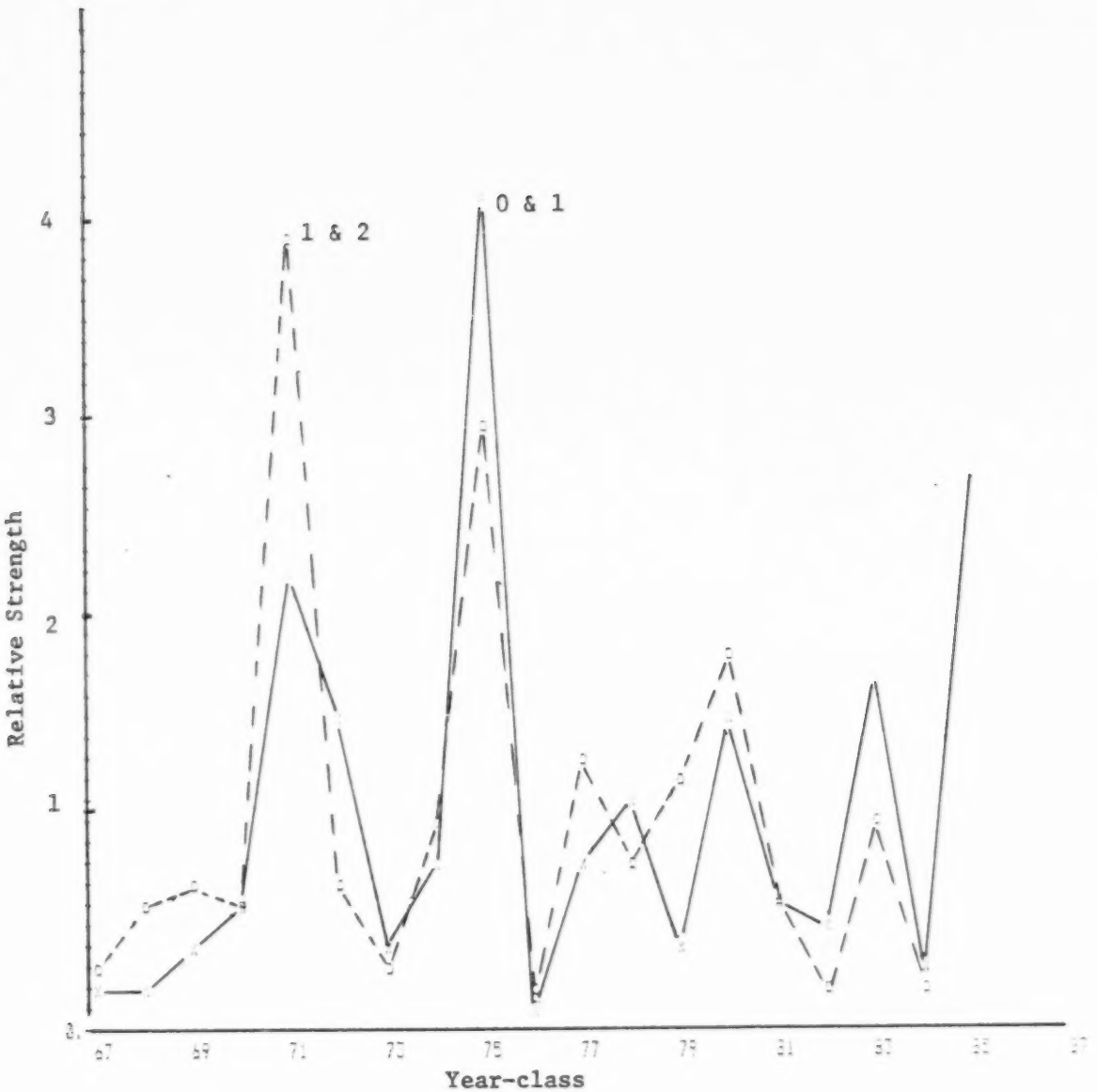
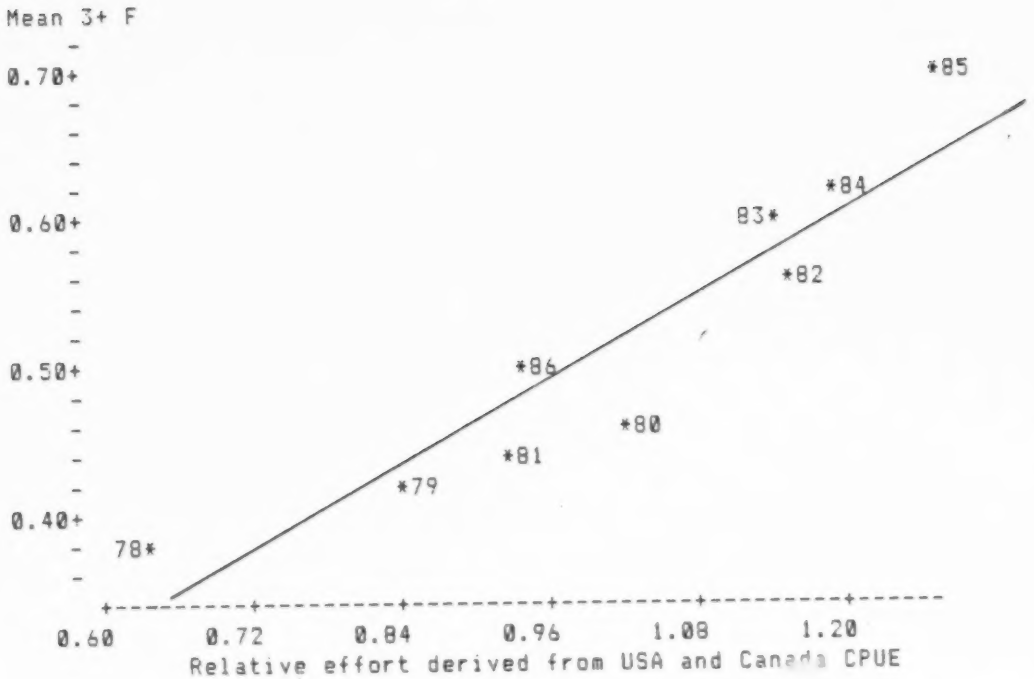


Figure 13. Relative strength of the 1967-85 year-classes of cod derived from catch per tow at ages 0, 1 and 2 in USA autumn survey.



The regression equation is
Mean 3+ F = 0.0343 + 0.480 Effort

R-sq = 86.9% R-sq(adj) = 85.0%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	0.072824	0.072824
Error	7	0.011021	0.001574
Total	8	0.083845	

	Effort	3+ F	Fit	Stdev.Fit	Residual	St.Resid
78	0.64	0.3900	0.3409	0.0295	0.0491	1.85
79	0.84	0.4170	0.4354	0.0182	-0.0184	-0.52
80	1.02	0.4680	0.5246	0.0132	-0.0566	-1.51
81	0.93	0.4380	0.4786	0.0146	-0.0406	-1.10
82	1.15	0.5650	0.5884	0.0166	-0.0234	-0.65
83	1.14	0.5910	0.5798	0.0159	0.0112	0.31
84	1.19	0.6210	0.6043	0.0181	0.0167	0.47
85	1.27	0.6910	0.6436	0.0225	0.0474	1.45
86	0.94	0.5000	0.4853	0.0142	0.0147	0.40

Figure 14. Regression of mean 3+ fishing mortality on relative effort derived from Canadian and USA directed CPUE.

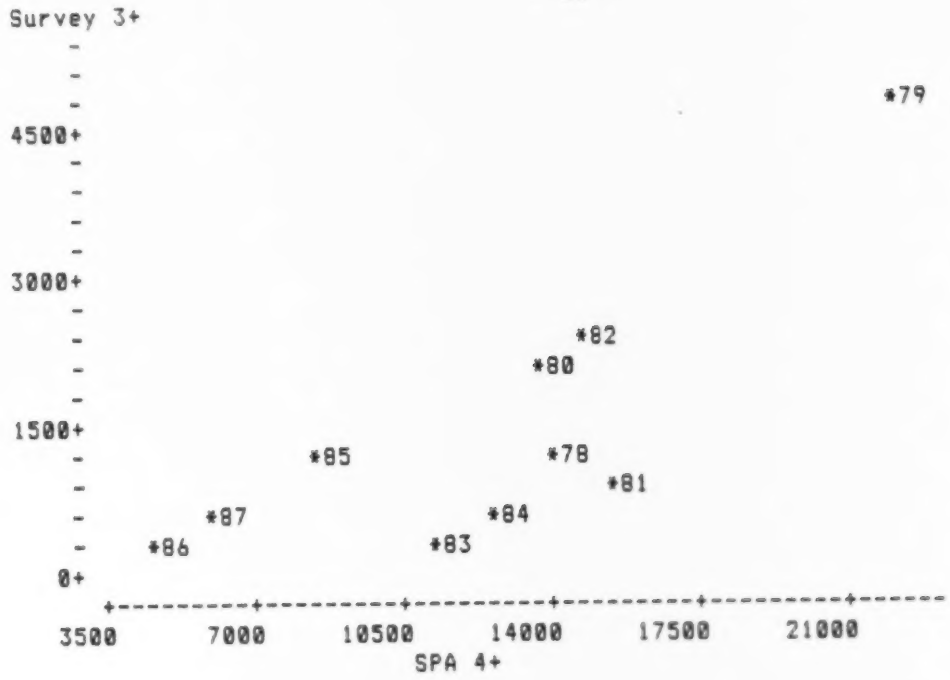


Figure 15. Relationship between USA autumn survey catch per tow at ages 3+ and SPA ages 4+ with 0.7 fishing mortality in 1986.

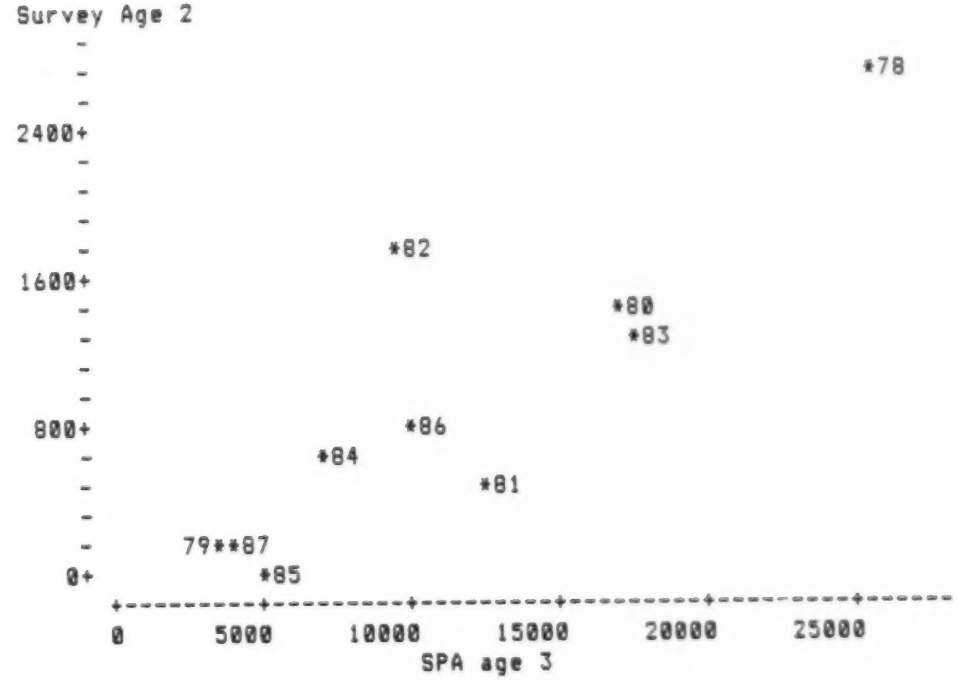


Figure 16. Relationship between autumn survey age 2 and SPA age 3 numbers with 0.7 fishing mortality in 1986.

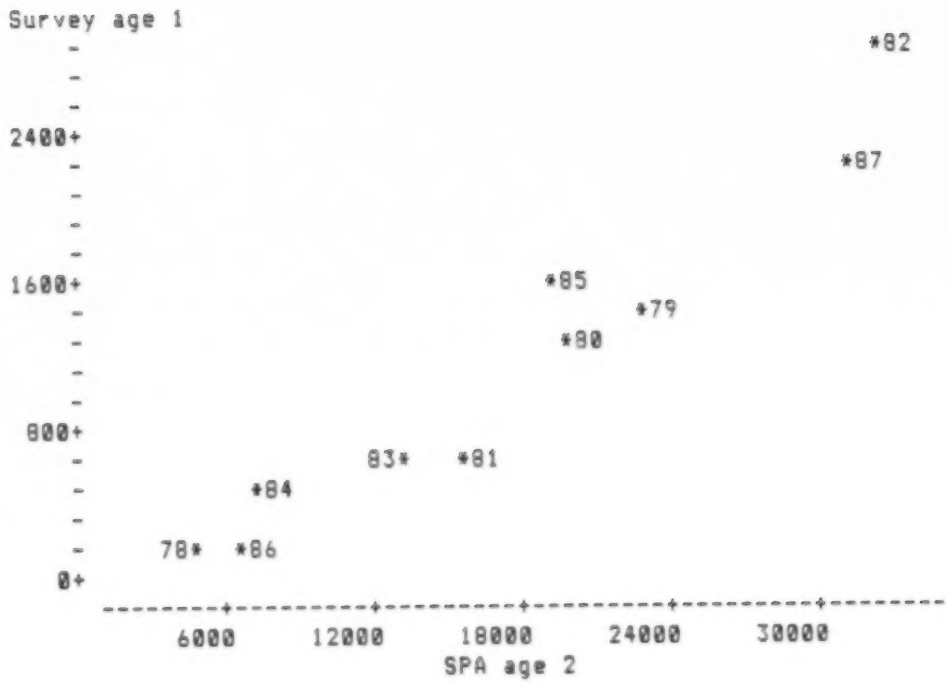


Figure 17 . Relationship between autumn survey age 1 and SPA age 2 numbers with Ft=0.7 and 35.7% partial recruitment in 1986.

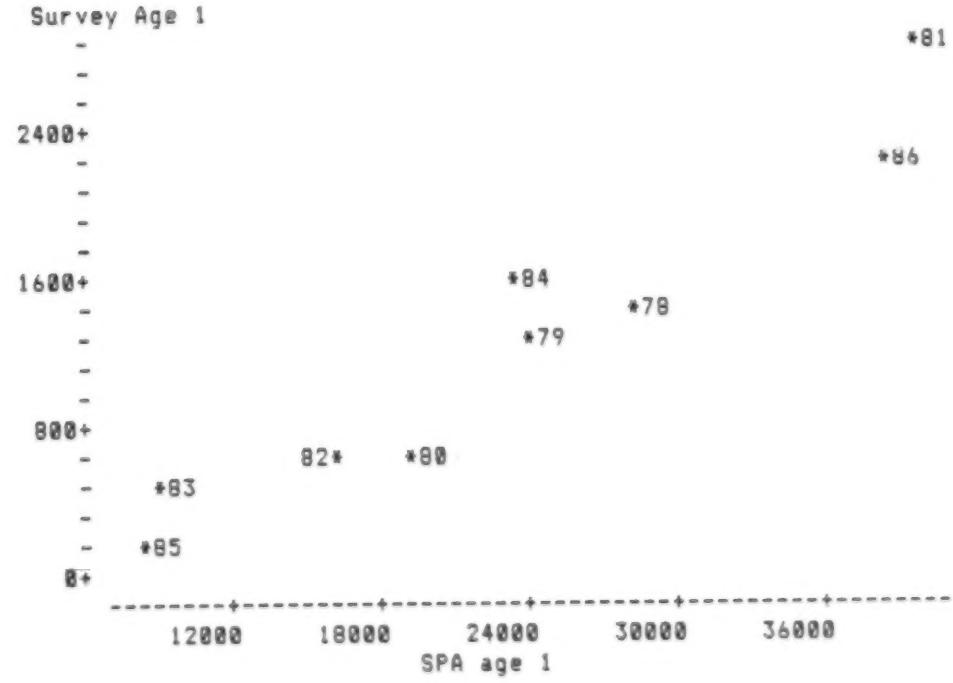


Figure 18 . Relationship between autumn survey age 1 (no lag) and SPA age 1 numbers with Ft=0.7 and 0.6% partial recruitment in 1986.

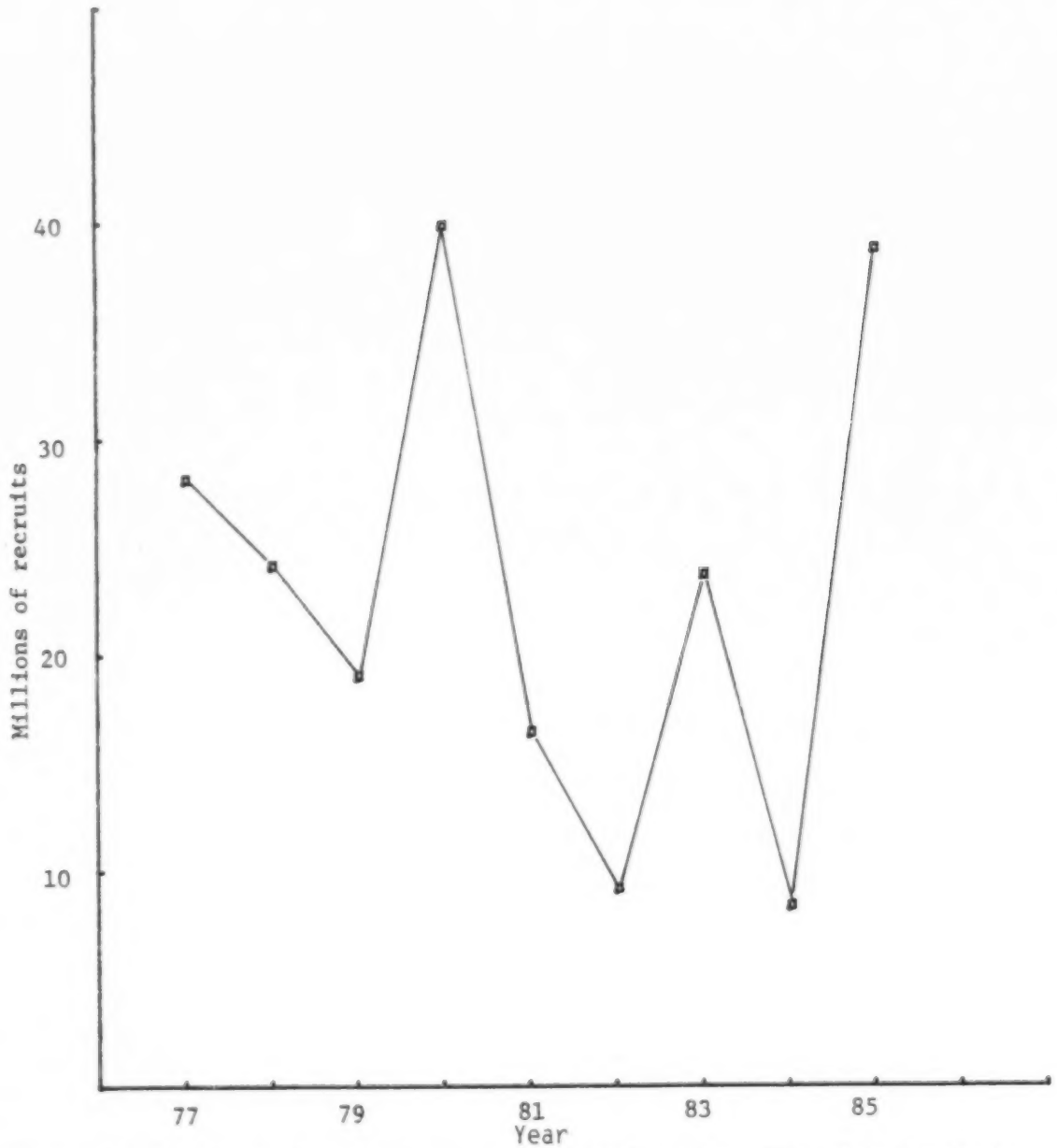


Figure 19. Estimated recruitment at age 1 derived from SPA with F_t set to 0.7

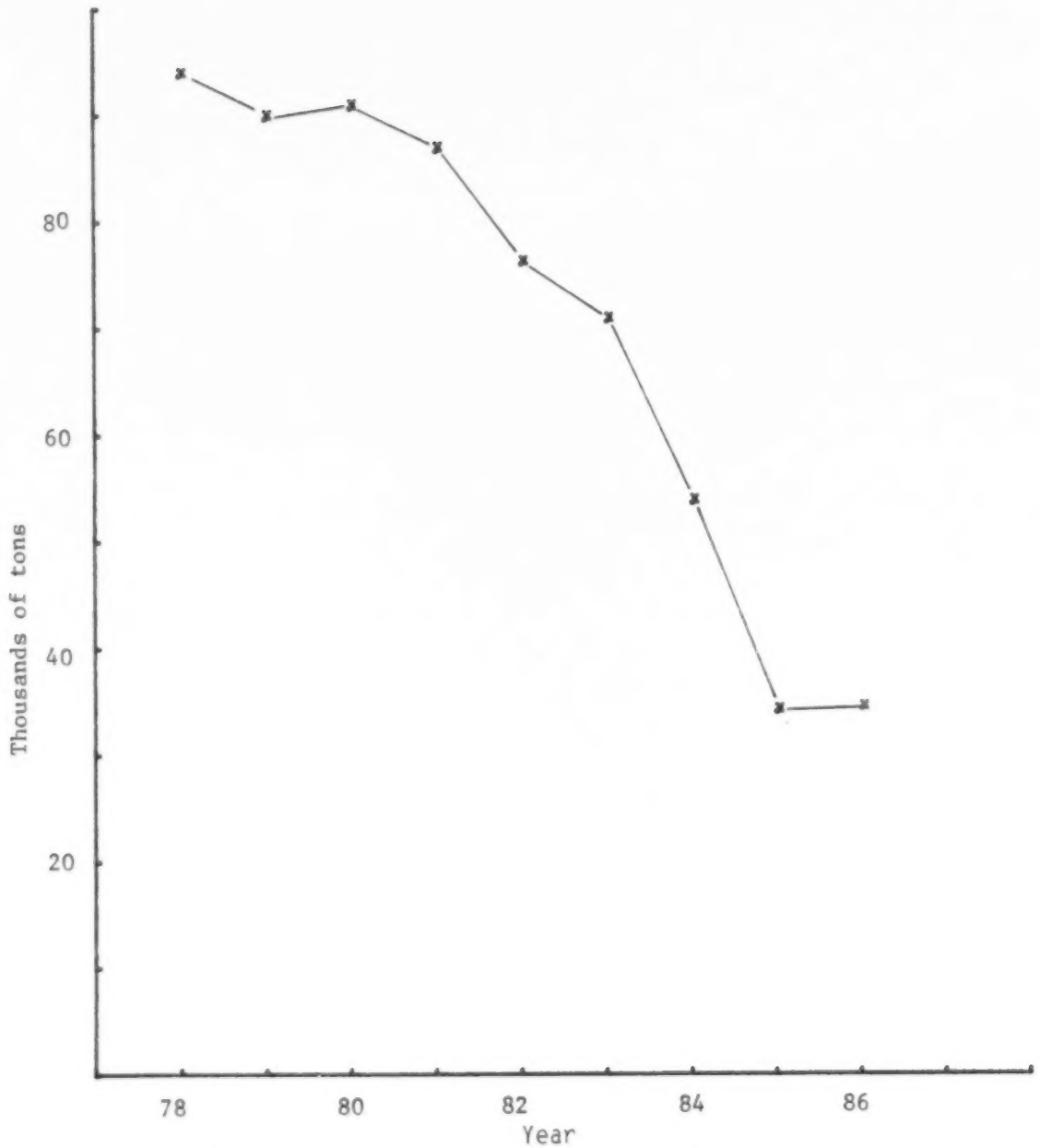


Figure 20. Estimated 3-plus biomass derived from SPA with F_t set to 0.7, for 1978-86.